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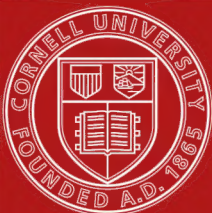
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FOOD AND DIETETICS

FOOD

AND THE

PRINCIPLES OF DIETETICS

BY

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WITH PLATES AND DIAGRAMS

FIFTH EDITION

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TO THE
STUDENTS OF THE LONDON HOSPITAL
TO WHOM ITS CONTENTS WERE FIRST ADDRESSED,
AND BUT FOR WHOSE ENCOURAGEMENT
IT WOULD NOT HAVE APPEARED IN ITS PRESENT FORM,
THIS VOLUME IS DEDICATED
BY
THE AUTHOR.

PREFACE TO THE FIFTH EDITION

DURING the five years and more which have elapsed since the publication of the last edition of this book the experiences of war and famine have compelled more attention than ever before to the problems of diet and nutrition. Some progress has been made, especially perhaps in the direction of an increased appreciation of the different biological value of the various proteins and of the importance of the vitamins in dietetics. In the present edition more prominence has been given to these matters.

As a co-opted member of the Food (War) Committee of the Royal Society, and afterwards as Medical Adviser to the Ministry of Food, the writer obtained considerable experience of the problems of rationing, the results of which are to some extent embodied in the earlier chapters. In the sections dealing with the economic values of foods pre-war prices have still been retained, as present prices are still so unstable. This will not be found, however, in the author's belief, to invalidate the inferences drawn as to the relative economic value of different foods.

In the chapters dealing with feeding in disease the writer would again point out that his object has been to explain the principles upon which dietetic treatment should proceed, rather than to construct menus, believing as he does that, if these principles are grasped, it should not be difficult to draw up a detailed diet suited to the circumstances of the individual patient. In this part of the book the chief changes will be found in the section dealing with Diabetes.

LONDON, *December*, 1921.

PREFACE TO THE FIRST EDITION

THE contents of this book were first addressed to the students of the London Hospital in the form of a course of lectures about a year and a half ago. The very gratifying reception accorded to these lectures and the almost total neglect of the subject of dietetics in ordinary medical education have induced the author to publish them in their present form.

While the book has been specially designed to meet the requirements of students and practitioners of medicine, it is hoped that it may also prove intelligible and interesting to anyone desiring to acquire some knowledge of foods and the difficult problems of nutrition.

In recasting the lectures for publication a large amount of additional material has been used, and no pains have been spared to make the book fully representative of the present state of our knowledge on the subject of which it treats. A considerable amount of space has been devoted to the patent and proprietary foods, and an effort has been made to deal fairly and honestly with their merits. The great number and variety of these now offered for sale makes this specially necessary.

As far as possible original papers have always been consulted, and references to these will be found in the footnotes; but if, as is only too probable, some important publications have been overlooked, the vast extent of the literature of the subject must be taken as the author's excuse.

The author feels also that he is under a great obligation to the

many able systematic writers on the subject who have preceded him, both in this country and on the Continent, and whose names are too well known to require special mention here. He would like, however, to take this opportunity of expressing his special indebtedness to the work and writings of Professor Atwater and his colleagues in America, who have done so much in recent years to advance our knowledge on the principles of dietetics. The opening chapters, especially, of the present book owe much to the teaching of the American school.

To Dr. Leonard Hill and the writer's other colleagues at the London Hospital Medical College he must express his gratitude for much encouragement and useful advice, and to his friends Dr. J. J. R. Macleod and Mr. Robert Tanner he is indebted for the pains which they have bestowed on the revision of the proof-sheets.

The illustrations have been drawn by Mr. Danielsson with his usual skill, and the care with which Mr. Archibald Clarke has compiled the index has saved the author much labour.

LONDON, *October*, 1900.

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1 gramme	=	15·4 grains.	
1 kilogramme	=	2 pounds 3 ounces.	
<hr/>			
1 ounce	=	28·3 grammes.	
1 pound	=	453·5	„
1 fluid ounce	=	28·4 c.c.	
1 pint	=	568	„
<hr/>			
1 pint	=	20 fluid ounces.	
1 tumblerful	=	10	„ „
1 breakfastcupful	=	8	„ „
1 teacupful	=	4	„ „ (approx.).
1 claret glassful	=	4	„ „
1 sherry-glassful	=	2	„ „
1 tablespoonful	=	one-half fluid ounce.	

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FOOD AND DIETETICS

CHAPTER I

THE NATURE, NUTRITIVE CONSTITUENTS, AND RELATIVE VALUES OF FOODS

A food may be defined as *anything which, when taken into the body, is capable either of repairing its waste or of furnishing it with material from which to produce heat or nervous and muscular work.*

I am aware that this definition is open to criticism, as most definitions of the term have been before it, and that it is difficult to refuse to oxygen especially the right to be regarded as a food under the terms of such a description. But for practical purposes the definition may be allowed to stand, and it has the advantage of bringing into prominence the two main functions of food—in the first place, as a provision for the growth and repair of the fabric of the body, and, secondly, as a source of potential energy which can be converted into heat and work. In virtue of the former function, food provides for the conservation of the material of the body; the conservation of bodily energy is maintained by the latter.

Substances which are unable to help in either of these directions may have a useful place in the dietary, but they cannot be truly regarded as foods. Examples of such substances are to be found, as we shall learn later, in tea, coffee, and the extractives of meat.

Most ordinary articles of diet are not simple bodies; they are made up of mixtures of various chemical substances, some of which are of nutritive value, while others are not. The former may be spoken of as

the nutritive constituents or 'nutrients,' and may be classified as follows:

Organic—

1. Nitrogenous:

Proteins, *e.g.*, casein, myosin, gluten, legumin.
Albuminoids, *e.g.*, gelatin.

2. Non-nitrogenous:

Carbohydrates, *e.g.*, sugar, starch.
Fats, *e.g.*, olive-oil, butter.

Inorganic—

Mineral matters, *e.g.*, sodium, potassium, lime, phosphorus, chlorine.

Water.

Any article of diet, even the most elaborate product of the cook's art, can be shown, by chemical analysis, to contain one or more of the members of these different groups; otherwise it is not a 'food' at all.

The functions of food are fulfilled by the different groups in different measure. The first function, that of building up and repairing the tissues, can be fulfilled by the proteins and by the inorganic constituents, and by these alone. For this purpose protein, mineral matters, and water are all necessary. None of the three is sufficient by itself. The second function, that of serving as a source of potential energy, is the property of all the organic constituents, although there is a limited sense in which water, and even, perhaps, the mineral constituents, may be regarded as sources of energy too (see p. 288).

The comparison of the body to a steam-engine is a rather threadbare and not altogether accurate analogy, but it is, perhaps, the best that can be found. The building material of food corresponds to the metal of which the engine is constructed, the energy-producers to the fuel which is used to heat the boiler. Where the body differs from the engine is that it is able to use part of the material of its construction (protein) for fuel also.

In regard to the relative values of the organic constituents as energy-producers, physiological opinion has undergone considerable changes in the last fifty years. It used to be supposed, mainly as the result of the powerful advocacy of Liebig, that the proteins were the chief producers of muscular energy, while the carbohydrates and fats merely acted as fuel and maintained the body temperature. We now know that this was a mistaken view. It would seem, indeed, to be to a large extent a matter of indifference to the *cells* of the body whether they draw their supplies of energy from protein, albuminoids,

carbohydrate, or fat, although probably they can get it more rapidly and easily from the three former than from the latter. We now know also that bodily heat is not a thing apart and requiring to be provided for by itself, but that it is an inevitable accompaniment of cell life. Life and heat are inseparable, and in fulfilling its other functions in the body a cell cannot help producing heat also. Heat, in fact, is a by-product of functional activity (see also p. 48). Hence it is a matter of indifference as far as the cells of the body are concerned—not necessarily, be it remembered, as far as concerns the digestive organs—whether we feed a man on white or egg, gelatin, butter, or sugar, always supposing that these are supplied in the proportion of their dynamic equivalents.

As regards the manufacture and repair of tissue, however, no such indifference prevails. That can be done by protein, mineral matters, and water, and by these alone. Even the albuminoids, near though they stand to the proteins, and large though the proportion is in which they enter into the bodily framework, can take no share in tissue formation. This is true, curiously enough, even of the connective tissues, from which gelatin is itself derived.

One may therefore classify the nutritive constituents of food, in accordance with their functions in the body, as follows :

<i>Tissue-formers.</i>	<i>Work and Heat Producers.</i>
Proteins.	Proteins.
Mineral matters.	Albuminoids.
Water.	Carbohydrates.
	Fats.
	? Mineral matters.
	? Water.

It will be observed that proteins alone are able to fulfil both of the functions of a food. It is this physiological omnipotence which gives to proteins their vast importance in the diet, and justifies the proud title of 'pre-eminent' which the name implies. Without protein life is impossible, for the daily wear and tear of tissue must somehow be made good. With protein, plus water and some mineral salts, life can be healthily maintained for a practically indefinite time, as is proved by the experience of tribes such as the Indians of the Pampas, who live year in year out on nothing but lean beef and water.

Such being the uses of foods in the body, the question arises, How is one to judge of their relative value? By what criteria is one to decide whether any particular article of diet is a good food or not? The reply is that such a question can only be decided by submitting the food under consideration to these four tests :

1. *Chemical*.—What percentage of each nutritive constituent does the food contain?
2. *Physical*.—How much potential energy is it capable of yielding?
3. *Physiological*.—How does it behave in the stomach and intestine? Is it easily digested, and to what extent is it absorbed?
4. *Economic*.—Are the nutritive constituents which the food contains obtained at a reasonable cost?

The methods by which each of these tests is applied must now be considered.

1. **The Chemical Test**.—Chemical analysis can tell us how much of each nutritive constituent (protein, carbohydrate, etc.) a hundred parts of the food contain. By the aid of this information we can form an idea of the value of the food as a source of building material or energy. In subsequent chapters the percentage composition of all the chief articles of food will be brought forward in detail, and some types of these will be referred to immediately.

2. **The Physical Test**.—Ever since Lavoisier showed that the changes which food undergoes in the body are essentially changes due to oxidation, the idea has gathered weight that the amount of heat which a food is capable of yielding on complete combustion may be taken as a measure of its value as a source of energy, for heat and work are convertible terms. Now, the standard of heat production is the calorie, which means the amount of heat required to raise the temperature of 1 gramme of water 1° C. This is the small calorie. For measuring the heat value of foods, one employs for convenience the large, or Kilo-calorie—*i.e.*, the amount of heat required to raise 1 kilo (or 1 litre) of water 1° C., or, which is the same thing, 1 pound of water 4° Fahr.; and one writes it **Calorie**, with a capital letter. All that one has to do in applying this test is to ascertain of how many litres of water the complete combustion of 1 gramme of the food under consideration is able to raise the temperature by 1° C. The result gives the value of 1 gramme of the food in terms of Calories. A large number of very careful experiments of this sort have been made in recent years with the aid of the bomb-calorimeter, the results of which are graphically represented in the following diagram (Fig. 1).

The suspicion naturally arises that, although these results hold good for combustion outside the body, they may not be equally true for combustion in the tissues. This suspicion is strengthened when one remembers that many of the waste products of metabolism, such as urea, are by no means completely oxidized. The body does not reduce all its fuel to the condition of ashes; some of it is only charred. Careful observations by Rubner, however, have shown

that, if allowance is made for these incompletely oxidized products, combustion inside the body is precisely the same, as far as the amount of energy liberated is concerned, as combustion in an ordinary furnace, and that the heat value of 1 gramme¹ of each of

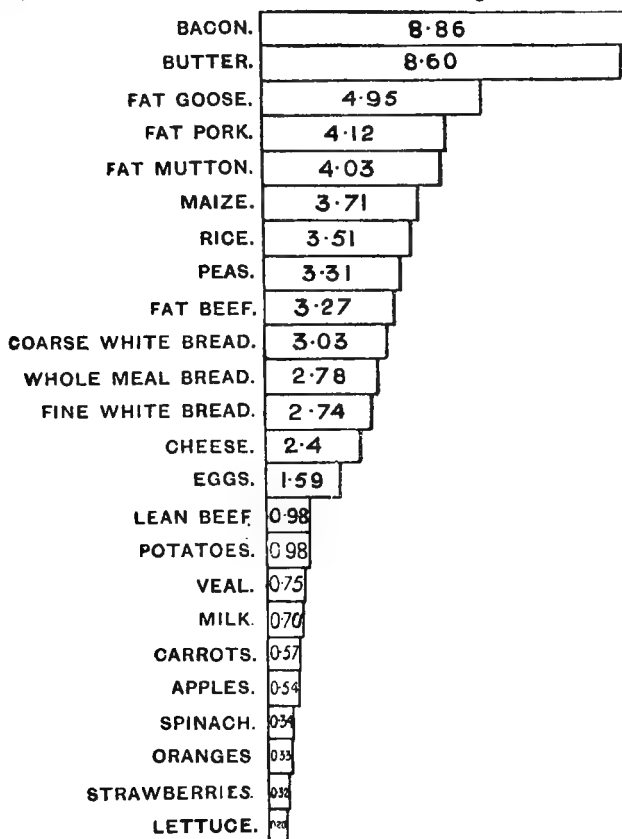


FIG. 1.—NUMBER OF CALORIES YIELDED BY THE COMPLETE COMBUSTION OF ONE GRAMME OF VARIOUS FOODS.

the three chief nutritive constituents of food when taken into the tissues is as follows :²

Protein	..	..	..	..	..	4.1	Calories.
Carbohydrates	..	..	..	..	..	4.1	"
Fat	..	..	..	..	..	9.3	"

¹ A gramme = 15½ grains. A shilling weighs about 5½ grammes.

² These figures represent the average Calorie value of the nutritive constituents as contained in an ordinary mixed diet, and after allowance has been made for defective absorption and for the excretion of imperfectly oxidized residues by the kidney. They may therefore be taken as indicating the true worth to the body of the different nutritive constituents as sources of potential energy

The white of one egg contains 4 grammes of protein, a small lump of sugar contains the same weight of carbohydrate, and a thimbleful of olive-oil a similar amount of fat, so that the latter will yield twice as much energy in the body as the white of a whole egg or a small lump of sugar.

In the Calorie, then, we have a standard which is as applicable in estimating the energy value of foods as the foot-rule is in measuring length or the ounce in calculating weight. But great as the value of this standard is—and, indeed, it is the only absolute standard by means of which all foods may be compared—one must not over-estimate it. Just as in a furnace some substances, such as anthracite, are 'slow,' and others, such as petroleum, are 'quick' fuels, so in the human body some of the nutritive constituents seem to yield their energy to the cells more rapidly than others. Thus, proteins, carbohydrates, and albuminoids seem to be oxidized quickly in the tissues, fats more slowly. And this is not a matter of indifference, for if a rapid output of energy is required, the first group will be more serviceable, whereas a slow production over a long time will be equally well met by fat (see also p. 39). Further than this, the situation in which the energy is liberated must also be taken into account. It may be a matter of indifference, as far as the heat produced is concerned, whether oxidation takes place in the liver or in the muscles; but as regards the bodily function, of which, as we have seen, the production of heat is but an accompaniment, there is all the difference in the world. The time and the place, in short, have to be considered, as well as the actual amount of the energy liberated. The physical test of a food enables us to judge of the latter; it tells us nothing of the two former.

The method of applying the Calorie standard to a food is very simple. One has merely to multiply the percentage of protein or carbohydrate which it contains by 4·1, and the percentage of fat by 9·3, to get the total Calories yielded by 100 grammes of the food in question. Suppose, for example, that a specimen of milk contains in every 100 grammes 2 per cent. of protein, 4 per cent. of fat, and 6 per cent. of carbohydrate, then the Calories yielded by that quantity of milk would be as follows:

Protein	..	..	..	..	..	..	$2 \times 4 \cdot 1 = 8 \cdot 2$
Fat	..	..	..	..	..	..	$4 \times 9 \cdot 3 = 37 \cdot 2$
Carbohydrate	..	..	..	..	..	..	$6 \times 4 \cdot 1 = 24 \cdot 6$
Total Calorie value of 100 grammes of the milk							<u>70·0</u>

In Plate I. there is represented the number of Calories contained in 1 pound of some typical foods, and the proportions of these

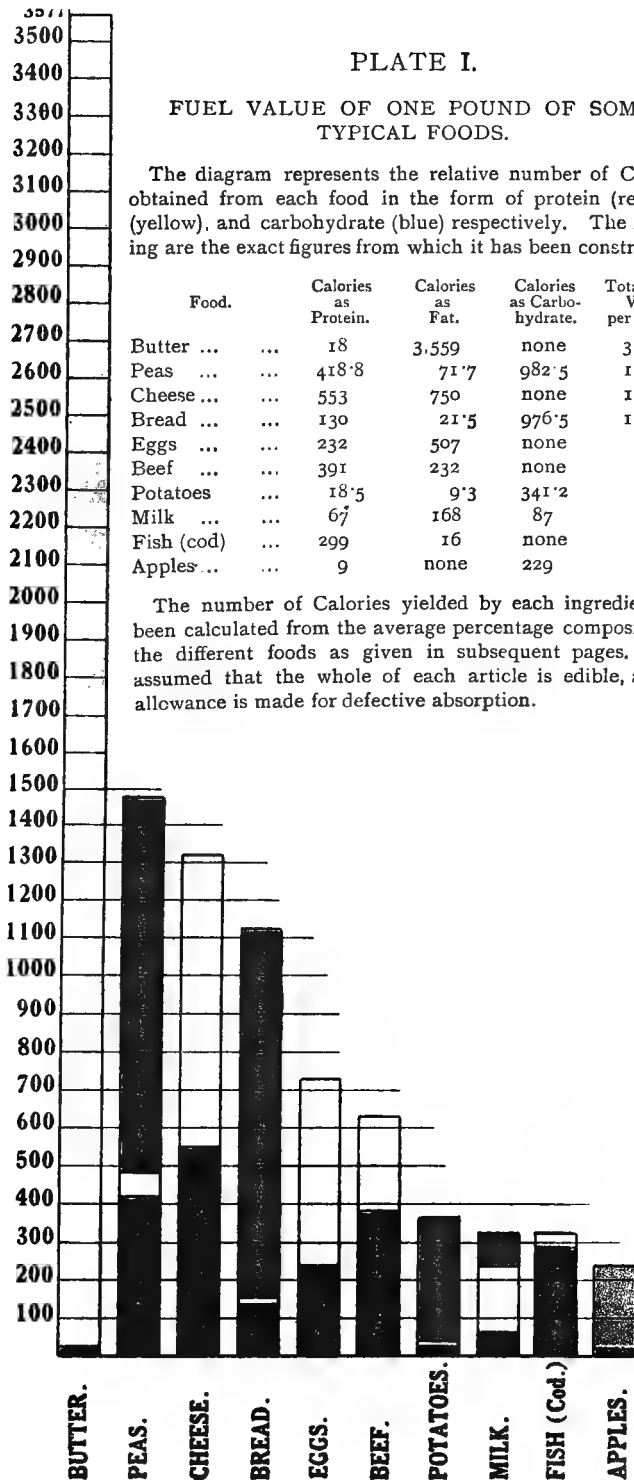
PLATE I.

FUEL VALUE OF ONE POUND OF SOME TYPICAL FOODS.

The diagram represents the relative number of Calories obtained from each food in the form of protein (red), fat (yellow), and carbohydrate (blue) respectively. The following are the exact figures from which it has been constructed :

Food.	Calories as Protein.	Calories as Fat.	Calories as Carbo- hydrate.	Total Fuel Value per Pound.
Butter ...	18	3,559	none	3,577
Peas ...	418·8	71·7	982·5	1,473
Cheese ...	553	750	none	1,303
Bread ...	130	21·5	976·5	1,128
Eggs ...	232	507	none	739
Beef ...	391	232	none	623
Potatoes ...	18·5	9·3	341·2	369
Milk ...	67	168	87	322
Fish (cod) ...	299	16	none	315
Apples ..	9	none	229	238

The number of Calories yielded by each ingredient has been calculated from the average percentage composition of the different foods as given in subsequent pages. It is assumed that the whole of each article is edible, and no allowance is made for defective absorption.





which are yielded by protein, fat and carbohydrate respectively. It will be noticed that butter heads the list as far as the total number of Calories yielded is concerned. This is due to the large amount of fat which it contains. In potatoes, on the other hand, the Calories yielded are mainly derived from carbohydrates, while in cheese and beef the total yield is produced by protein and fat in nearly equal proportion. In other words, as a producer of energy, a pound of butter is worth about three times as much as a pound of cheese, and more than five times as much as a pound of beef; but as a source of building material both cheese and beef are vastly superior to it. The following table represents the approximate energy-value of one ounce of some standard articles of food. It may prove of assistance in appraising the value of any diet as a source of energy :

TABLE OF ENERGY VALUES OF SOME FOODS.

Food.	Energy Value per Ounce (in Calories).	Food.	Energy Value per Ounce (in Calories).	Food.	Energy Value per Ounce (in Calories).
Beef, lean, cooked	60	Butter	222	Potato, boiled	.. 25
" fat	93	Plasmon	86	Carrots, raw	.. 11
Lamb, cooked	.. 62			Cabbage, raw	.. 8
Veal	.. 66	Cheese, American	118	Spinach	.. 10
Pork	.. 88	" Cheddar	134		
Fowl	.. 80	" Cheshire	113	Figs, dried	.. 92
Duck	.. 47	" Dutch	90	" stewed	.. 50
		" Stilton	124	Prunes	.. 87
Tongue, tinned	.. 84	" Camembert	95	Raisins	.. 106
Sweetbread, raw	.. 50	" Cream	170	Apples, raw	.. 14
Liver, raw	.. 38			Grapes	.. 20
Kidney, raw	.. 32	Egg .. (in one)	70	Bananas	.. 28
Calf's-foot jelly	.. 25				
Cod, raw	.. 20	Flour, white	.. 100	Almonds	.. 174
Salmon, raw	.. 60	Bread, "	.. 70	Walnuts	.. 182
Halibut	.. 35	" wholemeal	62	Hazel-nuts	.. 190
Eel	.. 36	Biscuits	.. 112		
Herring	.. 41	Rusks	.. 98	Sugar	.. 115
" smoked	.. 85			Marmalade or jam	98
Haddock, raw	.. 20	Oatmeal	.. 130		
" smoked	27	Rice	.. 98	Beer, bottled	.. 17
Mackerel, raw	.. 40			Stout	.. 20
Turbot	.. 55	Sago	.. 96	Lager beer	.. 14
Sardines in oil	.. 80	Tapioca	.. 96	Hock	.. 18
Oysters	.. 15	Arrowroot	.. 96	Claret	.. 18
		Macaroni	.. 100	Port	.. 41
Milk	.. 20			Sherry	.. 38
Cream (45 %)	.. 126	Peas (dried), raw	92	Spirits	.. 83
		" (green), "	22		

Owing to the great variations in the composition of foods the energy values given in this table are merely approximative; in the case of some foods, such, for example, as bacon and ham—the variations are so great as to render any statement as to the average value useless. In every case the value of the edible

portion of the food is alone represented, and allowance has been made for loss in assimilation. So far as possible, the energy value has been calculated for the food as prepared for the table, but in many instances, owing to the elaborate methods of cooking employed, this has been found impracticable, and the value of the raw food is given instead. (For further information on this point see a paper by Schwenkenbecher, 'Die Nährwerthberechnung tischfertiger Speisen,' in the *Zeitsch. f. Physik. und Diät. Therapie*, iv., 1901, p. 380.)

3. The Physiological Test.—It is not enough that a food should contain a considerable proportion of protein, carbohydrate and fat, and should be capable of yielding energy on oxidation. It must also be of such a nature that it can be easily digested in the stomach, and more or less completely absorbed into the blood. Such substances as sawdust, petroleum, and hoof-parings might pass the chemical and physical tests easily enough, but they are of no use in the body, for they cannot be digested and absorbed. For this reason the behaviour of a food in the stomach and intestine must be reckoned with before any opinion can be pronounced as to its value in the diet.

In studying this subject, one must distinguish very clearly between the meaning of the term 'digestibility' in its popular sense and that attached to it by physiologists. When one speaks of a food as being 'indigestible,' one ordinarily means that it is a food which is apt to produce feelings of pain and discomfort in the stomach. When a physiologist uses the term, he usually means that the food to which it is applied is one which is only imperfectly absorbed into the blood. Cheese is an indigestible food in the former, and green vegetables in the latter, sense. To avoid confusion, it is better to adhere to the popular usage of the expression 'digestibility,' and, if one may use a rather ugly word, to employ the term 'absorbability' to indicate the completeness with which the constituents of a food can pass from the intestine into the circulation.¹

By a **digestible food**, then, I mean one which is disposed of by the stomach with little trouble, and without producing any feelings of discomfort or pain. The only absolute criterion of the digestibility of a food in that sense is the length of time which it has to remain in the stomach before it is fit to be passed on into the intestine. The shorter the time a food needs to stay in the stomach, the greater is its digestibility; and the longer the period which must elapse before it can pass on into the intestine, the more indigestible it is.

In a subsequent chapter we shall have occasion to study the results of a large number of exact experiments which have been

¹ In this nomenclature 'digestibility' would correspond to the German *ertragbarkeit*, and 'absorbability' to *ausnutzbarkeit*.

performed to ascertain the length of time which different foods remain in the stomach—experiments, that is to say, on the comparative digestibility of foods. I would only point out here some of the factors which are of importance in determining the length of time required in any particular case. It must be borne in mind that one of the chief duties of the stomach is to reduce the food to a fluid or semi-fluid condition. The more difficult the process of solution is, the longer must the food remain in the stomach. Now, bulky foods, and those of a dense and firm consistency, or which contain a large proportion of solid matter, will take longer to dissolve, and will consequently remain longer in the stomach than foods of opposite properties. Obviously, then, foods of such a character may be regarded as comparatively indigestible. In addition to these factors, certain others must be taken into account, such as the temperature of the food, the proportion of fat which it contains, and the presence or absence of substances in it which are capable of exciting the secretion of the digestive fluids. All of these will be fully considered later on.

Before leaving the subject, mention must be made of one other quality of foods which seems specially to affect the stomach, and which, for want of a better term, is commonly called their **satisfying power**. It is a matter of common knowledge that some foods appease the appetite and allay the feelings of hunger longer than others. Such foods are said to be ‘satisfying,’ or, to use a slang expression, ‘stodgy.’ What it is which confers this quality upon some foods rather than others is not perfectly clear; but there is reason to believe that it depends to some extent upon the amount of fat which the food contains. Foods rich in fat are more satisfying than others. It is believed to be for this reason that eggs possess the quality under consideration in no ordinary degree. Other properties, such as the amount of solid matter to be digested and the bulk of the food, no doubt also play a part in producing the feeling of ‘satisfaction’; but whatever the explanation of the quality is, it has certainly to be reckoned with in estimating the value of a food from the stomach point of view.

ABSORBABILITY.

A large number of experiments have been performed in recent years in order to ascertain the degree to which the different constituents of various foods are absorbed into the blood. The average results for the chief groups of foods are shown in the following table:¹

¹ U.S. Dept. of Agriculture, Office of Experiment Stations, Circular 110.

**COEFFICIENTS OF DIGESTIBILITY AND AVAILABILITY OF
ENERGY OF DIFFERENT GROUPS OF FOOD.**

Kind of Food.	Protein.	Fat.	Carbo- hydrates.	Availability of Energy.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Meat and fish	97	95	—	87
Eggs	97	95	98	89
Dairy products.. .. .	97	95	98	93
Total animal foods of mixed diet ..	97	95	98	89
Cereals	85	90	98	91
Legumes, dried	78	90	97	83
Sugars and starches	—	—	98	98
Vegetables	83	90	95	91
Fruits	85	90	90	88
Total vegetable foods of mixed diet	84	90	97	92
Total food	92	95	97	91

The method of experiment consists in analysing the food to be investigated, and then ascertaining, from an examination of the fæces, the proportion of its protein, carbohydrate and fat which escapes absorption.

In the accompanying diagram (Plate II.) there is shown the percentage of each nutritive constituent which is unabsorbed in some typical foods. It will be well to consider each constituent separately.

1. *Absorption of Proteins.*—One of the first points which arrest the attention on looking at the diagram is that, of the three chief nutritive constituents, the proteins are the least completely absorbed. Whether this is quite an accurate way of stating the case, whether one should not rather say that foods differ more in regard to the waste of nitrogen which they cause than in any other respect, is, as has been shown, a matter of indifference. The fact remains that with some foods much nitrogen is excreted in the fæces, with others little. Closer inspection will show that in this respect foods may be divided into two groups. On a purely animal diet (milk, eggs, beef) there is but little nitrogen lost; whereas with vegetable foods (carrots, potatoes, peas, etc.) the waste of nitrogen is very considerable, amounting in the case of carrots to nearly 40 per cent. of the total protein consumed. The reason for this loss of protein on a vegetable diet will be considered later (p. 169), but it must be pointed out here that the smaller the amount of nitrogen a food contains, the greater is the apparent loss of it in the fæces, for the higher is the ratio of the nitrogen derived from the digestive juices to that in the food. This explains, to some extent at least, the great apparent loss of protein in such foods as carrots and rice.

2. *Absorption of Fat.*—Compared with the proteins, fat is apparently very completely absorbed. This probably means that the residue of the intestinal juices contains almost no fat; hence nearly all of that which appears in the fæces is derived from the unabsorbed fat

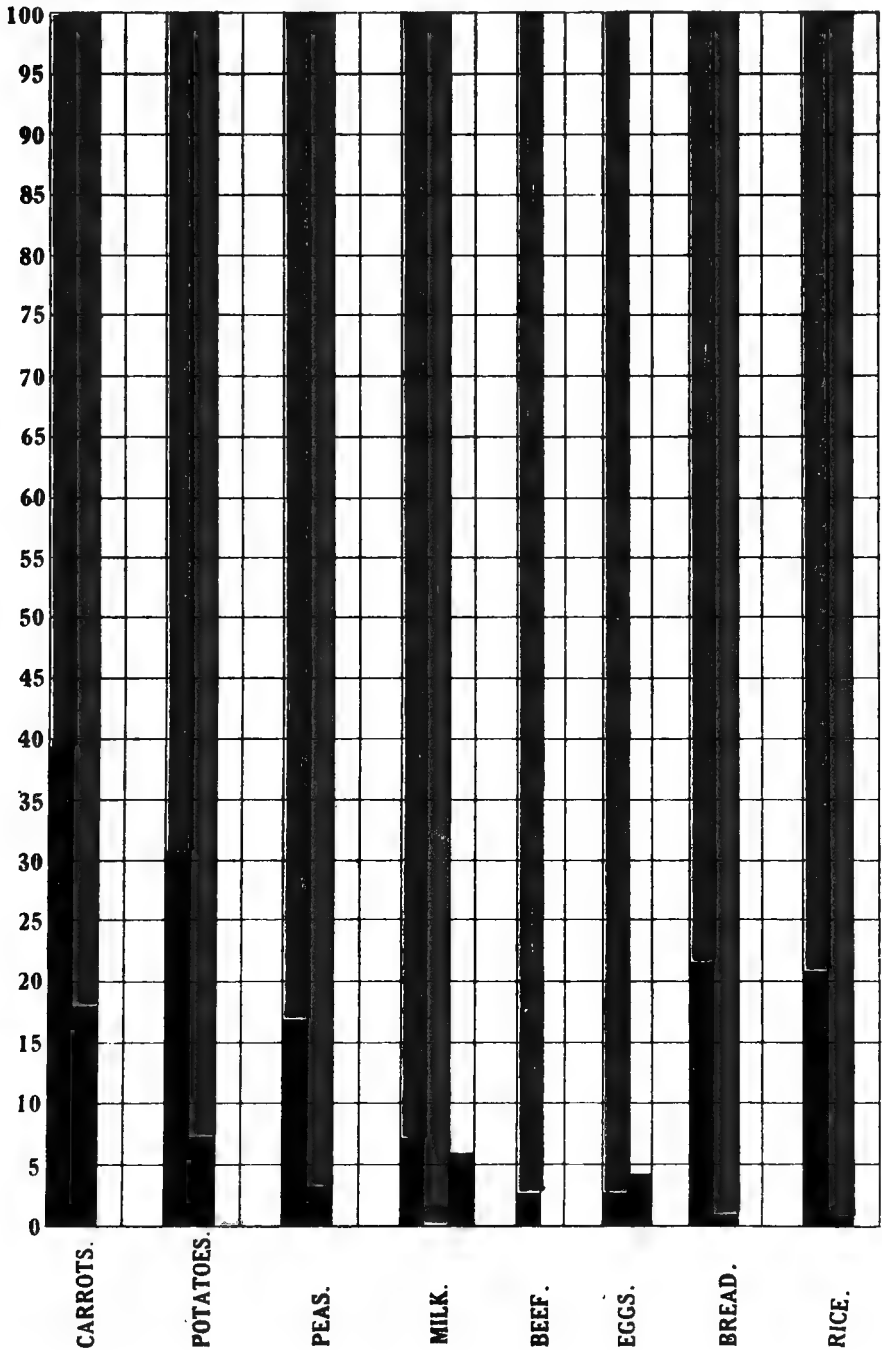
EXPLANATION OF PLATE II.

The percentage of protein (red), carbohydrate (blue), and fat (yellow) not absorbed in each food is blacked out. The actual amounts are as follow :

			Percentage not Absorbed.		
Food.			Protein.	Carbohydrate.	Fat.
Carrots	...	...	39	18'2	—
Potatoes	...	...	30'5	7'4	—
Peas ...	...	...	17'5	3'6	—
Milk ...	...	...	7'1	—	5'3
Beef ...	...	...	2'6	—	—
Eggs ...	...	...	2'6	—	4'4
Bread	...	...	21'8	1'1	—
Rice ...	...	...	20'4	0'9	—

PLATE II.

PERCENTAGE OF NUTRIENTS NOT ABSORBED IN SOME TYPICAL FOODS.



of the food. In the case of most of the vegetable foods, the amount of fat which they contain is so small that its absorption cannot be accurately estimated.

Regarding the absorbability of fat, one generalization can be made with a fair amount of certainty, and it is this: the lower the melting-point of the fat, the more completely is it absorbed. The explanation of this, of course, is that a fat which is fluid at the body temperature is more easily taken up into the blood than one which remains more or less solid. The following are illustrative examples:

<i>Fat.</i>			<i>Melting-point.</i>	<i>Percentage unabsorbed.</i>
Butter ..	..	..	37° C.	2½
Bacon ..	..	..	48° C.	8
Mutton-fat ..	..	..	52° C.	10

The total amount of fat which can be absorbed in one day is a matter of some interest. It has been found by experiment that 150 grammes (about 5½ ounces) can be absorbed without appreciable loss. Above this point the waste increases considerably, but even when twice that quantity is taken the loss is less than 45 per cent. The practical deduction from these facts is that one need have no hesitation in ordering a patient, say a diabetic, to consume ½ pound of butter every day. There is no likelihood of this quantity surpassing the absorptive powers of the intestine.

3. *Absorption of Carbohydrates.*—As is clearly shown in the diagram, the carbohydrates are more completely absorbed than any other nutritive constituent of the food. Sugar probably never fails to enter the blood to the last grain, and even starch only reappears in the fæces when taken in a form specially difficult of absorption, such as in green vegetables or in coarsely divided masses. Hence it is that foods which consist mainly of carbohydrates, such as rice, leave, on the whole, less solid residue in the intestine than any other, animal foods not excepted. In other words, the statement sometimes made, that vegetable are less perfectly absorbed than animal foods, is not universally true, although it may hold good in the majority of cases.

Seeing that a given weight of fat represents about two and a quarter times as much energy as an equal weight of protein or carbohydrate, it is evident that the loss to the body of a given amount of fat through non-absorption is of more importance than an equal loss of any of the other nutritive ingredients. For this reason it is perhaps more instructive to represent the percentage of the total Calories which a food contains which are lost in this way, rather than to give, as has been done above, the actual loss of each

constituent. Adopting this plan, it will be found that the loss in some typical foods is as follows :

<i>Food.</i>	<i>Percentage of Calories lost through Non-absorption.</i>	<i>Food.</i>	<i>Percentage of Calories lost through Non-absorption.</i>
Rice	2.6	Meat	5.5
Milk	4.4	Potatoes ..	6.8
Bread	4.5	Carrots ..	20.2

(Rubner.)

It will be observed that from this point of view rice and milk are much more economical foods than potatoes and meat.

ABSORPTION OF A MIXED DIET.

Most of the above experiments have necessarily been made when the subject of them was living upon a single article of diet only. But in ordinary life most people live upon a mixed diet, and it becomes necessary to inquire to what extent absorption goes on under these circumstances, and how the presence of one food in the intestine affects the absorbability of another. In general terms it may be said that the constituents of a mixed diet are better absorbed than those of any one article of food when taken by itself. This comes out very clearly in some observations recorded in America.

An average of eleven experiments¹ on ordinary mixed diet gave the following results :

<i>Constituents.</i>	<i>Percentage absorbed.</i>	<i>Constituents.</i>	<i>Percentage absorbed.</i>
Organic matter	95.7	Fat	94.4
Protein	92.6	Carbohydrate	97.1

In another experiment² the diet consisted of beef, eggs, bread and butter, milk, potatoes and fruit. The following were the percentages absorbed :

Protein	94.9	Carbohydrate	98.9
Fat	96.9		

In a third set of experiments³ the subject lived upon beef, white and brown bread and butter, milk, oatmeal, potatoes and fruit, and absorbed of their constituents the following amounts :

Protein	91.3 per cent.	Carbohydrate	97.7 per cent.
Fat	95.9 „		

The absorption of protein is more favourably influenced by the presence of a mixture of foods than is that of any other con-

¹ Wait, United States Department of Agriculture, Bull. 53.

² Ninth Annual Report, Storrs Agricultural Experiment Station, p. 179.

³ *Ibid.* A very complete summary of all the existing experiments upon the absorption of foods will be found in Bull. 45, United States Department of Agriculture, 1898.

stituent. This is probably to be explained by the fact that the production of organic acids from the carbohydrates of a mixed diet exerts a restraining influence upon the destruction of proteins in the intestine by putrefactive bacteria.¹ Thus, it has been found by actual experiments that the constituents of bread and milk are better absorbed when these foods are taken together than when either is consumed alone.² The same was found by Rubner to hold good for a mixture of milk and cheese, as compared with either of these articles taken separately.

Taking the general results of all experiments, it has been calculated that the following proportions of nutritive constituents will be absorbed from a mixed diet³:

		<i>Protein.</i>	<i>Fat.</i>	<i>Carbohydrates.</i>
Animal foods	98	per cent.	97	per cent.
Cereals and sugars ..	85	"	90	"
Vegetables and fruits ..	80	"	90	"
Ordinary mixed diet ..	92	"	94½	"

The following table⁴ represents the average 'physiological value' of some diets after allowing for losses from defective absorption and the excretion of incompletely oxidized residues, such as urea:

<i>Diet.</i>	<i>Percentage of Total Calories available for Purposes of Nutrition.</i>					
Human milk	91.6
Cow's milk (infant)	90.7
" " (adult)	89.8
Mixed diet, rich in fat	90.4
" " poor in fat	89.3
Bread	82.1
Potatoes	92.3
Meat	76.8

It may be asked whether it is to be regarded as an advantage in a food that it is completely absorbed. The reply would be that a food which leaves a moderate amount of unabsorbed residue is certainly preferable. The intestine seems to require a certain amount of **ballast**—probably to act as a stimulus to its peristalsis. If herbivorous animals, such as rabbits, are fed upon a diet which leaves little or no residue, it has been found that they suffer from affections of the intestine which may even prove fatal, whereas such effects can be avoided by adding to the food any material which leaves behind an unabsorbed residue. Even in the case of man, who has a considerably shorter intestine, it is observed that a diet

¹ The fatty acids liberated from neutral fats may perhaps act in a similar way.

² Bull. 53, United States Department of Agriculture, p. 44, 1898.

³ Atwater, Storrs Agricultural Experiment Station, Ninth Annual Report, p. 187. 1896, and Bull. 117 Off. of Experiment Stations, U.S. Dept. of Agriculture, 1902.

⁴ Rubner, *Zeitsch. f. Biologie*, 1901, xlii., p. 261.

which is practically completely taken up into the blood, such as one composed exclusively of meat, is prone to be accompanied by intestinal disturbances. On the other hand, a diet which leaves behind a very large residue is not only wasteful in an economic sense, but demands for its manipulation and evacuation an undue amount of muscular and nervous energy on the part of the intestine. This, as we shall see later, is one of the drawbacks to a purely vegetable diet. In conditions of disease it may be necessary to take advantage of the behaviour of different foods in respect of absorption. If peristalsis is exaggerated, as in diarrhoea, one does well to select those foods which are most completely absorbed, *e.g.*, rice, minced meat, or milk. In the opposite condition of diminished peristalsis and constipation, it is important to supply the intestine with a larger amount of 'ballast' than usual, and such foods as green vegetables and whole-meal bread most perfectly fulfil the requirements of the case.

Before leaving this subject two questions present themselves for consideration. The first is, may there not be individual differences in absorptive capacity? In other words, may some persons not extract the nutritive constituents from their food more thoroughly than others? It might be supposed that in this way some anomalies in dietetics would find an easy explanation, such, for example, as the unequal amounts of fat and flesh laid on by different individuals on the same diet. Tempting though this explanation is, it must be admitted that there are no exact observations in favour of it, but rather the reverse. It has been found, for example, that persons who have been accustomed to a purely vegetable diet for years absorb its constituents no better than those to whom such a regimen is a comparative novelty (see p. 179). The large number of observations which have been made on different individuals with the common articles of food have also failed to elicit any striking disparity in the degree to which absorption takes place, and even where the intestines are considerably deranged by disease there is a remarkable tendency for the ordinary degree of absorptive capacity to be maintained.

The second question which arises is this, Granted that the constituents of two foods are absorbed with equal completeness, may it not be true that the process of absorption demands a greater expenditure of energy in the one case than the other? Undoubtedly it is so; or, rather, the amount of energy which requires to be expended in order to reduce a food to a state in which absorption is possible may be greater in one case than in another. It has been found, for example, that for the same amount of protein actually

absorbed three to four times as much energy has to be expended in the case of bread as in that of milk. This is one of the advantages of a milk diet. Its absorption demands but little intestinal labour. That such labour is by no means inconsiderable is shown by the fact that, of the total amount of energy supplied to the body by a diet of bread and butter, fully 5 per cent. is expended merely in its digestion and absorption.¹

It seems likely that in future more attention than hitherto will require to be paid to this aspect of digestion.

Reviewing the results yielded by the application of the physiological test to foods, it must be admitted that they are of great value. Had it always been carefully applied, certain common dietetic fallacies would never have gained the wide prevalence they at present enjoy. Examples of these are the supposed superiority of whole-meal to white bread (p. 216), and the erroneous notion that the fungi might, if properly taken advantage of, prove a cheap and valuable source of food. A more egregious instance is to be found in the idea that petroleum can act as a substitute for cod-liver oil. I have elsewhere² advanced experimental evidence to prove that petroleum cannot be absorbed by the human intestine. It is thus ruled entirely out of the class of true foods by the application of the physiological test, even if it were, as it is not, admissible to that class in virtue of its chemical properties.

Maly has aptly compared foods to ore, and their nutritive constituents to the metal which the ore contains. Just as the metal has to be extracted from the ore before it is of any use, so, by the process of digestion, the nutritive constituents have to be extracted from a food before they can be absorbed. The chemical test tells us how much metal is present in the ore; the physiological test tells us whether or not the body is capable of extracting it.

4. The Economic Test.—Having ascertained the richness of a food in nutritive constituents, the amount of energy which it is capable of yielding, and the readiness with which it can be digested and absorbed, we have still to inquire whether the nutriment which it affords is obtained at a reasonable cost. For this we require an economic test. The simplest way of applying such a test is to find out how much energy (in Calories) and how much building material (in protein) one can get for a particular sum when invested in the food under consideration. In the following diagram (Plate III.) the results of the application of this test to various typical articles of diet are set out. Looking first at the energy (Calories) obtained, one

¹ Pawlow, 'Die Arbeit der Verdauungsdrüsen,' p. 89.

² *British Medical Journal*, 1899, i. 724.

sees that bread leads the way, a shilling invested in bread yielding 10,764 Calories, or more than three times as much as is obtained for the same sum in milk, and more than ten times as much as can be got in the form of beef.

In the matter of *building material*, on the other hand, peas come first, a shilling's worth containing 572 grammes of protein, or fully twice as much as can be obtained in cheese for the same expenditure. In the form of eggs or beef building material is even more costly, the former being more than eight, and the latter more than five, times as expensive a source of protein as peas.

Taking the results as a whole, it will be observed that the vegetable foods are far cheaper than the animal foods, whether one uses them as sources of energy or of building material. This is one of the strongest arguments in favour of vegetarianism.

Of the various nutritive constituents of food, carbohydrate is by far the cheapest. The reason is that carbohydrates make up the chief bulk of most vegetable foods, and these are, as we have just seen, considerably cheaper than the foods of animal origin. The further question, why vegetable foods *are* cheap, will be considered in another chapter (p. 181).

Compared with the carbohydrates, protein and fat are very expensive constituents of foods, fat, perhaps, especially so. 'It is a remarkable fact,' says Buckle,¹ 'and one to which I would call particular attention, that owing to some more general law, of which we are ignorant, highly carbonized food is more costly than food in which comparatively little carbon is found.' The 'more general law' of which he speaks is really the same law by which animal foods are dearer than vegetable. By far the larger part of the fat in our diet is derived from animal sources. The dearth of fat is unfortunate, and is not uncommonly a source of trouble in practical dietetics. One might mention, as an instance, the difficulty which a diabetic, who has at the same time the misfortune to be a poor man, finds in providing himself with a diet suited to his disease. The same remark applies, though less forcibly, to protein.

The practical importance of having an economic test for foods is the more convincingly felt when one realizes that the market price of a food is no indication of its real money value. In the market one pays for flavour and rarity, not for nutritive qualities. It is the demands of the palate which cost, not those of the stomach, and we pay for æsthetic qualities in foods just as in dress we pay for 'cut' and ornament, not for material to keep us warm. Suppose, for example, that one wishes to buy a pound of fish. If sole is the

¹ Buckle, 'History of Civilization,' vol. i., p. 62.

Calories.

10,500

10,000

9,500

9,000

8,500

8,000

7,500

7,000

6,500

Grammes

600

550

500

450

400

350

300

250

200

150

100

50

0

BREAD.

PEAS.

POTATOES.

MILK.

BUTTER.

APPLES.

CHEESE.

FISH.

EGGS.

BEEF.

PLATE III.

AMOUNT OF ENERGY (CALORIES) AND BUILDING MATERIAL (PROTEIN) GOT FOR ONE SHILLING IN SOME TYPICAL FOODS.

In this diagram the Calories yielded by each food are shaded; the protein is represented by the red lines. The exact figures are as follow :

Food.	Calories Yielded.	Protein Yielded (in Grammes).	Assumed Cost.
Bread ...	10,764	283	1½d. per lb.
Peas ...	8,921	572	2d. „
Potatoes ...	3,796	54	1d. „
Milk ...	3,000	114	1½d. per pint.
Butter ...	2,884	3.5	1s. 3d. per lb.
Apples ...	2,856	27	1d. „
Cheese ...	2,638	272.5	6d. „
Fish ...	953	218	4d. „
Eggs ...	839	79	1s. 0d. per doz.
Beef ...	829	127	9d. per lb.

Fifteen per cent. of the weight has been deducted in the case of potatoes to allow of waste from peeling. It is assumed that the other foods are entirely edible.



form selected, it may cost 1s. 6d.; haddock would yield quite as much nutriment for 4d.; *i.e.*, in the former one is paying 4d. for nutriment, and 1s. 2d. for other qualities. Or take the case of arrowroot. A pound of the best Bermuda costs 2s. 9d., St. Vincent only 3d. or 4d. Yet both are, in a chemical sense, merely starch, and physiologically their behaviour is identical. It is the same with cheese. A pound of Stilton costs 1s. 2d. The same amount of nutriment can be had in Dutch or American for 6d. These examples might be multiplied indefinitely, but they are sufficient to show that the maxim 'cheap and nasty' does not hold good for foods. I should be sorry to deny that æsthetic considerations should not be taken into account in selecting a dietary. It may be true that the sense of taste is as much worth cultivating as that of sight or hearing, but if one resolves to go in for luxury it is well to do so knowingly, and not imagine that one is nourishing the body while merely pleasing the palate.

To students and practitioners of medicine, a knowledge of the economic value of foods is of special importance. It is frequently our duty to see that the diet of a patient is enriched in special directions, most commonly, perhaps, in that of protein or fat. There is no use in recommending to a poor man chicken and cream. He cannot afford to buy them. It is worth while to remember, however, that the cheapest sources of building material are *skim* milk, some forms of fish (*e.g.*, herring or salt fish), cheese, the cheaper cuts of meat, and, if his digestion be good, the pulses, while the most economical forms of fat are margarine and dripping. These articles are within the reach of almost everybody.

To the poorer classes, too, such knowledge is of special value. It must be remembered that, of the wages which a working man receives, fully 50 per cent. *must* be spent on food alone, and that the poorer a man is the larger is his proportionate expenditure on this item. And yet the pathetic thing is that it is just this class of the community whose food purchases are apt to be the most irrational. There is room here for popular instruction.¹

Of two other points which concern the economy of foods no mention has been made; I refer to 'waste' and the cost of cooking. Of avoidable waste there is no need to speak, though in this country at least we have much to learn in that respect from some of our Continental neighbours. By *unavoidable* waste one means that a considerable

¹ See 'Family Budgets' (London: P. and S. King), 1896, and Oliver, 'The Diet of Toil, and its Relation to Wages and Production,' a paper read at the Congress of Hygiene and Demography, Buda-Pesth, September, 1894.

proportion of much food as purchased is not in an edible form; I refer to such things as the skin and skeleton of fish, the bone of meat, and some parts of green vegetables. In ordinary cuts of meat the unavoidable waste may be reckoned as about 15 per cent.; in fish it may sometimes rise as high as 70 per cent. This must certainly be taken into account in making purchases of food. In the diagram (Plate III.) allowance has been made for these waste matters, but no account has been taken of the cost of cookery. This is a matter which it is exceedingly difficult to estimate, as so much depends upon the cook, but the general value of the results is not seriously impaired by the omission.

VITAMINS.¹

From what has been said hitherto, it might be supposed that all that is necessary to constitute a normal diet is a sufficiency of protein, mineral matter and water, with the addition of enough carbohydrate and fat to supply the requisite number of calories to make good the energy requirements of the body. This, however, is by no means the case. It is a late discovery in dietetics that no diet is suited to the prolonged maintenance of health unless it also contains substances of doubtful chemical nature, but of great vital importance, which are known by the title of 'vitamins' or 'accessory food factors.' Our knowledge of the vitamins—which are only present in the food in extremely minute quantities—has been largely acquired by a study of the disease beri-beri. Careful observation of this disease showed that it is produced by the consumption of a diet consisting mainly of 'polished' rice, and that it can be prevented by the use of rice from which the pericarp has not been removed. These observations were confirmed and extended by the study of an analogous condition produced artificially in birds, and there is now no room for doubt that the husk of rice contains vitamins the absence of which induces the development of a form of neuritis known clinically as beri-beri. Further, it has long been known that scurvy results from a diet which lacks some constituent of unknown nature. It used to be believed that vegetable salts of potash were the ingredient required, but the observations of Axel Holst² on experimental scurvy in guinea-pigs have shown that here also we are dealing with a 'vitamin,' although a different one from that concerned in beri-beri. Not only can definite diseases such as those referred to result from the absence of vitamins, but there is also now reason to believe, as the result of the researches of Hopkins³ and others, that normal growth requires for its progress the presence in the diet of substances of a similar nature. Hopkins found, for instance, that if young rats are fed upon a diet which

¹ For a history of the discovery of vitamins and of the growth of our knowledge relating to them, see 'The Nutritional Importance of the Presence in Dietaries of Minute Amounts of Certain Accessory Substances' (*Brit. Med. Journ.*, 1913, i. 722). The literature of the subject has grown to very large dimensions in recent years, but the practical results are summarized in the Report of the Committee on Accessory Food Factors, published in 1919 (abstract, *Lancet*, July 5, 1919). See also Hopkins's Huxley Lecture, *Lancet*, January 1, 1921, and McCollum's 'The Newer Knowledge of Nutrition' (Macmillan, 1919).

² *Brit. Med. Journ.*, 1908, ii. 1366.

³ *Lancet*, 1913, ii. 1309.

contains the proper amount of the ordinary nutritive constituents, but which has been 'purified' by extraction with alcohol, growth ceases, but is at once resumed if even a minute amount of the alcoholic extract is added to the ration. The observations of Thompson¹ upon the relatively large gain in weight which may follow upon the addition to the diet of even a small quantity of meat extract are no doubt to be interpreted in a similar way.

There are, then, three varieties of vitamin which have been recognized up to the present:

(1) *Fat-soluble or A-growth factors (Vitamin A)* contained abundantly in animal fats (but not in lard), green vegetables, eggs, and glandular organs.

(2) *Water-soluble B or antineuritic (anti-beri-beri) factor (Vitamin B)*, contained in the germ of wheat, eggs, the pulses, glandular organs, nuts, and yeast.

(3) *Water-soluble, antiscorbutic factor (Vitamin C)*, contained in fresh fruits and vegetables, swedes and tomatoes, germinated pulses and cereals and, to a less degree, in fresh meat and milk.

As to the exact chemical nature of these vitamins we are still in the dark, for they have not yet been isolated; but we know that they are all derived from plants and that animals are incapable of building them up. Their mode of action is also obscure, but they appear to serve as catalysts or activators, which exert an intermediary influence in metabolism and render possible the assimilation of certain nutrients, probably phosphorus compounds. More definitely than this it is impossible to speak in the present state of our knowledge, but whatever they may be, we know that the vitamins are highly labile substances, which are easily destroyed by heat, drying, the action of alkalies, etc. Hence the ease with which they are removed in the preparation of foods.

Vitamin A is particularly necessary to young growing animals. Its absence from the diet interferes with development, and there is some reason to believe, though the matter is still *sub judice*, leads to the appearance of rickets.² In adults a deficiency of this vitamin appears to lower resistance to infections and brings about a disease of the eye (Keratomalacia).

Absence of Vitamin B from the diet is an important factor in producing the disease beri-beri, and also interferes with growth in young animals, whilst a deficiency of Vitamin C results in the appearance of scurvy.

Whether there are any other 'deficiency diseases' resulting from an insufficient supply of vitamins in addition to those already mentioned is not known, though it has been suggested that some vague conditions of ill-health may have such an origin.³ It is possible, too, that a deficiency of vitamins in the diet may play a part in the production of pellagra and 'famine dropsy.'

¹ *Brit. Med. Journ.*, 1911, ii. 613.

² Mellanby, 'An Experimental Investigation of Rickets' (*Lancet*, March 15, 1919). For a criticism of these results see Hess, *Journ. of the Amer. Med. Assoc.*, 1921, 76, p. 693.

³ For evidence in favour of this, much of it rather unconvincing, see McCarrison's 'Studies in Deficiency Disease' (Oxford Med. Publications, 1921).

CHAPTER II

THE AMOUNT OF FOOD REQUIRED IN HEALTH

IT was pointed out in the last chapter that the function of food is a double one: (1) to furnish material for bodily growth, and for the repair of the daily waste of the tissues; (2) to provide a supply of potential energy for expenditure in the form of heat and work. We have now to consider how much food must be supplied daily if these functions are to be efficiently carried out.

It will be convenient to consider the two divisions of the problem separately, and to discuss in the first place how much 'building material,' in the second, how much potential energy, is required daily. The building material in the diet consists, as we have seen, of protein, mineral matters, and water. I propose to defer to a later chapter the consideration of the amount of mineral matters and water which the diet should contain, and to confine myself at present to the discussion of the question:

How much Protein is required Daily?—It may be stated at once that to this question no conclusive reply has yet been furnished by physiology. This is unfortunate, for the problem is one the importance of which it would be impossible to exaggerate. It is, indeed, one of the most fundamental problems in the physiology of nutrition, and until it is finally solved dietetics cannot fairly claim to rank as an exact science.

In the succeeding paragraphs the results of the efforts which have been made to settle the question will be briefly set out.

An ordinary man on a freely-selected diet is found to excrete about 20 grammes of nitrogen daily. It may be assumed that all of this should be supplied in the form of protein, and as protein contains about 16 per cent. of nitrogen, it is obvious that

125 grammes of the former will be able to supply 20 grammes of the latter. As a matter of fact, that is the generally accepted standard for the amount of protein required daily, but it is by no means an absolute one. The reason for this is that the body is able to establish an equilibrium on very various quantities of protein. The typical man referred to above excretes 20 grammes of nitrogen daily, merely because he consumes that amount in his daily food. Had he consumed 15 grammes, he would only have excreted 15 grammes, and if his consumption had risen to 25 or 30 grammes or higher, his excretion would still have kept pace with it, for the body is unable to store up any surplus of protein, as it does of carbohydrate or fat. It is this tendency for the amount of nitrogen excreted to be exactly equal to the amount consumed which physiologists call the establishment of **nitrogenous equilibrium**, and it is evident that such equilibrium can be established on any quantity of protein which the digestive organs are capable of dealing with. The question, therefore, is, What quantity is best? To this, it may be at once confessed, no absolute reply can be given. When one recollects that the chief function of protein is to keep in repair the tissues of the body, one is tempted to suppose that all that is necessary is to consume enough for that purpose. Anything above that, it might be thought, would be mere extravagance—the *luxus consumption* of the older school of physiologists. But how to ascertain that bare amount? The reply at once suggests itself that in the amount of nitrogen excreted during starvation there will be found a measure of the amount which just suffices to keep the tissues in repair. A man who has been starving for some time excretes about 4 to 5 grammes of nitrogen daily,¹ but it is found that if merely this amount is supplied in the food it is not sufficient to establish equilibrium. Indeed, the smallest amount of nitrogen on which it is possible to establish equilibrium is found to be from three to four times the amount excreted during hunger. Should we, then, attempt to live on this minimum? This is a very difficult question. Remembering that, although the chief use of protein is to build up and repair the tissues, yet every gramme of it is also capable of supplying to the body 4·1 Calories of energy (p. 5), it is evident that the problem which confronts us can be stated in another way. Should we make use of protein *merely as building material*, relying upon carbohydrate and fat as our sources of

¹ For observations on fasting men, see 'A Digest of Metabolism Experiments,' United States Department of Agriculture, Bull. 45 (revised edition), p. 87, 1898.

energy, or should we also take advantage of its capability of providing for heat and work?

Before finally replying to this question another factor in the problem must be presented. We know from physiological experiment that the greater the quantity of carbohydrate and fat which is supplied along with protein, the less does the latter tend to be wasted in supplying energy, and the more of it there is available for the higher purpose of keeping the tissues in repair. The fat and carbohydrate are sacrificed instead of the protein. This is what physiologists mean when they describe fats and carbohydrates as **protein spacers**. But it is almost impossible so to arrange matters that *all* the energy shall come from fat and carbohydrate, and so leave all the protein free for repairing the fabric of the body. And for this reason: the cells of the body may be supposed to be bathed with lymph containing in solution particles of protein, fat, and carbohydrate derived from the blood. These particles are attacked by the cells and oxidized, heat and energy being liberated in the process. But the cells do not seem to be able to attack each of these constituents with equal ease. Of the three constituents mentioned, protein is most easily broken down, then carbohydrate, fat least easily of all. If, then, the three are present in equal proportion, there will always be more of the protein attacked than of the others. But if, on the other hand, carbohydrate and fat are present in great excess, they assert themselves by their mere 'mass influence,' and exclude many of the protein particles from ever coming into contact with the cell at all—crowding them out, so to speak—and so sparing the protein from destruction. It is almost impossible, however, to get the three chief nutritive constituents into the neighbourhood of the cell in such proportions that *none* of the easily-attacked protein is used up. By giving abundance of carbohydrate this object can be more easily effected than by fat, for, as we have seen, the cells have less difficulty in coping with the former than the latter. Gelatin is an even more efficient spacer of protein (see p. 77). Hence it is that those foods which contain a very large excess of carbohydrate along with a moderate proportion of protein, and in which both are absorbed and reach the cells at about the same rate—a most important point—will be the foods on which least protein is likely to be wasted and the largest fraction of it reserved for tissue repair. In other words, these will be the foods to have recourse to if one wishes to preserve nitrogenous equilibrium on a minimum amount of protein. In accordance with this, it has been found that nitrogenous equilibrium can be maintained on 1,500

to 1,600 grammes of bread containing only 104 grammes of protein, on 800 grammes of maize with 74 of protein, and on 3,080 grammes of potatoes in which the total protein amounts to not more than 54 grammes; and yet all of these quantities are sufficient to supply 3,000 Calories daily (Rubner).

Despairing of finding any reply to the question **What is the protein optimum?** on purely scientific grounds, physiologists have had recourse to two other methods of attacking the problem—viz., (1) by estimating the amount of protein contained in the freely-chosen diet of an average man doing a moderate amount of muscular work; (2) by testing experimentally the point to which the amount of protein in the diet can be reduced without any impairment of the health and efficiency of the individual resulting.

(1) The former of these methods was first employed, and upon its results the accepted dietary standards have hitherto been based. Any estimate of its validity, however, must depend upon the number and extent of the data upon which its conclusions are founded, and upon one's belief in the instinctive wisdom of mankind in matters of food. To the trustworthiness of its data, I think, no reasonable objection can be taken. A very large number of analyses of freely-chosen diets in various parts of the world have now been made (see p. 32), and they show, with a remarkable degree of unanimity, that the standard of protein adopted has been almost invariably something above 100 grammes. Where the standard falls below this the shortcoming is explicable either on the ground of insufficiency of means to purchase the average diet, or, as in the case of some Asiatics, by reason of the subject being an individual of small body-weight.

The objection, on the other hand, that this standard, though nearly universal, is not necessarily wise, cannot be met so easily, and its force will depend upon the relative weight which one attaches to instinct and to greed respectively, in determining the dietetic habits of mankind. For his own part, the writer is bound to point out that there is at least strong *a priori* reason for the belief that, in matters of diet, what has been adopted *semper et ubique et ab omnibus* is fundamentally right, especially when one remembers that protein is one of the more expensive nutritive constituents of the food, which it must often involve a good deal of struggle and sacrifice to obtain.

(2) Although certain individual vegetarians, and even vegetarian races, have for long been unconsciously employing the second method of attacking the problem of the protein optimum, Chittenden was the first to use it deliberately and experimentally on a sufficiently

large scale, and under rigid scientific conditions. His results showed¹ that in groups of professional men, athletes, and soldiers, nitrogenous equilibrium, health, and efficiency could be maintained for periods of some months on a daily intake of protein of less than 60 grammes, or about half that contained in most freely-chosen diets.

Chittenden and his followers do not shrink from the logical conclusion of these experiments. They believe that the protein standard of 120 grammes, which has been accepted ever since Voit first set it up, is far too high, that it is wasteful economically, and, not only so, but injurious to health, by throwing upon the organs of digestion, assimilation, and excretion an unnecessary amount of work. It need hardly be said that the champions of the orthodox standard have not been backward in subjecting Chittenden's experiments, and the conclusions founded upon them, to criticism, and, apart from technical questions as to his methods, the following summary of objections to the general adoption of a low protein standard may be stated :²

- (a) Although such a standard may be adopted with apparent impunity for a period amounting even to several months, it does not follow that it can be safely pursued for years. The *remote* consequences in a lowered resistance to disease and in general diminution of tone might well be injurious. As Rubner has put it,³ the excess of protein in the ordinary diet is to be regarded as a margin of safety, just as one builds a bridge considerably stronger than is necessary for the maximum load it has to carry.
- (b) There is reason to believe that persons who are accustomed to ingest but little protein are unable to assimilate an increased amount when necessary. In wasting diseases and in convalescence this would prove harmful.
- (c) The attempt to carry on life upon a minimum of protein may result in a loss of nitrogenous substance from the body in slight and temporary disturbances of health, which it may take weeks to replace.
- (d) If hard work is done on a small protein intake, the necessary energy can only be obtained by increasing the supply of fat

¹ See 'Physiological Economy in Nutrition.' New York: Frederick A. Stokes Co., 1904, and 'The Nutrition of Man.' London: Wm. Heinemann, 1907.

² For an able discussion of the whole question see Sir James Crichton Browne's 'Parsimony in Nutrition' (London and New York: Funk and Wagnalls Co.), 1909; and for detailed criticism of Chittenden's methods see Benedict, *Amer. Journ. of Phys.*, 1906, xvi. 409.

³ 'Volksernährungs-Fragen,' p. 47.

and carbohydrates to a point which may be greater than the digestive organs can comfortably stand.

- (e) The assertion that the prevalent protein standard is injurious to health is based upon insufficient evidence, and is opposed to universal experience.

It is perhaps safest to assume that the protein in the diet of the average man should not fall below 80 grammes a day; that it should be derived from mixed sources, and should contain, if possible, a certain amount of animal origin. Provided there is a free choice of foods, and the Calorie intake is sufficient, the diet is sure to contain at least this minimum of protein. As Professor Bayliss has put it, 'Look after the Calories, and the proteins will look after themselves.' Meanwhile this must be said: that whatever may prove to be good for an ordinary adult, there can be no question that in the case of children, adolescents, and pregnant women, it is far safer to adopt a high protein standard than a low one. No risk must be run of providing an insufficiency of material for the complete building up of the growing organism.

We may now turn to the other division of our problem, and ask:

HOW MUCH POTENTIAL ENERGY SHOULD THE DIET CONTAIN?

This question, being purely one of physics, is much more easily capable of exact solution, and fortunately the reply given to it by physiologists is fairly definite and unanimous. The data necessary for its solution may be obtained in two ways. There is first what one may call the purely *physiological method*. A man is shut up in a respiration-calorimeter. All the heat which he gives out from his body in a given time is measured, and the work which he does is also measured and expressed in terms of heat. The result stated in the form of Calories gives the amount of energy which has been expended by the body in a given time, and consequently the amount of potential energy which must be supplied in the form of food to maintain equilibrium. Such a method is necessarily very laborious, and only a limited number of observations by it are yet available; but there can be no doubt that it will be much more largely employed in the future. The results yielded by this method, when translated into quantities of ordinary food-stuffs, form the basis of **standard dietaries**.

By far the larger number of observations have been made by

what may be called the *empirical method*. A healthy individual living under known conditions, and on a freely-chosen diet, is selected; the food which he eats and the excreta given off from his body are analyzed, and in this way one discovers whether or not the income in diet is equal to the expenditure as represented by the waste products excreted and the state of the individual's weight. The method may be modified by varying the diet in different directions, and seeing how each change affects the balance-sheet of the body, or groups of persons living under similar conditions may be chosen instead of individuals, and the average amount of food required calculated from the total consumed by the group. Such observations have mostly been made on the inmates of public institutions. From the data yielded by this method **actual dietaries** can be drawn up, some examples of which will be given immediately. A study both of standard and actual dietaries shows that a man of average weight (11 stones), and doing a moderate amount of muscular work, must be supplied daily with an amount of energy in the form of food which is the equivalent of about 3,000 Calories.¹

We have now to ask, What proportion of this total should be supplied in the form of protein, carbohydrate, and fat respectively? As regards protein, we have already seen that the amount recommended by most physiologists is 120 grammes daily, which would yield about 15 per cent. of the total energy required. We have only to consider the remaining question—

HOW MUCH CARBOHYDRATE AND FAT SHOULD THE DIET CONTAIN?

As far as the demand of the cells for energy is concerned, it is within limits a matter of indifference how much of the total energy required is obtained in each of these forms, provided one remembers always that it takes $2\frac{1}{4}$ parts of carbohydrate to supply as many Calories as 1 part of fat. To the digestive organs, however, it is by no means a matter of indifference. If all the energy not provided as protein were to be supplied in the form of carbohydrate, it would mean that a large *bulk* of food must be consumed, which would be not only apt to overload the stomach and intestines by its mere weight, but would also be prone to undergo fermentation, leading to

¹ That is, *net* Calories. The total must be increased by at least 10 per cent. to allow for the difference between the food as purchased and as digested and assimilated. About 3,400 gross Calories may be taken as the standard daily requirement of food energy as bought (see pp. 29 and 36).

the production of flatulence and acidity. If, on the other hand, fat be adopted as the exclusive source, one would run the risk of overstepping the limits of fat absorption, and nausea, and probably diarrhoea, would ensue. In this matter habit and personal peculiarity have a great influence. There are some races, such as the Esquimaux, who take almost the whole of their energy in the form of fat; others take it mainly in the form of carbohydrates. The Scotsman is notoriously less inclined to eat fat than the Englishman, and one constantly meets with individuals who have an insuperable repugnance to the consumption of even moderate amounts of fat. We have already seen that 150 grammes of fat can be absorbed daily without much difficulty, but in most persons anything above 100 grammes ($3\frac{1}{2}$ ounces) in winter, and rather less in summer, would be apt to produce disorders of digestion. For this reason alone, therefore, it is well to take a mixture of carbohydrate and fat rather than either of these exclusively, and 50 grammes of fat ($= 2\frac{1}{2}$ ounces of butter) to 500 of carbohydrate ($= 1$ pound 2 ounces of sugar) may be regarded as a reasonable proportion. This is in the ratio of 1 part of fat to 10 of carbohydrate. Many authorities, however, recommend that the daily ration of fat should not fall below 75 grammes.

The question of expense also comes in here. Fat is a dear but compact form of energy; carbohydrate is bulky but cheap. Those who can afford it usually try to get the advantages of a condensed food, in spite of its greater cost; while those to whom pecuniary considerations are of importance must put up with the inconveniences of the more bulky food in exchange for its greater cheapness.

Hence one finds that, as a matter of observation, the food of the rich is usually much more fatty than that of the poor.

Opportunity, also, is a determining factor. The Esquimaux eats much fat because he cannot grow crops; the Hindoo consumes much carbohydrate because he has got facilities for growing rice.

Here, as in so many other cases, necessity determines the choice, and custom makes it the most agreeable.

Notwithstanding the above considerations, to which the practical solution of the question must usually be left, it is still of some scientific interest to ask whether there may not be some part played in the body by fat which is not so well fulfilled by carbohydrates, and *vice versa*. There is not much in the way of experimental evidence to help us in coming to a conclusion on this point, but there is a prevailing belief among competent observers that in the

diet of children, at least, a deficiency of fat cannot be replaced by an excess of carbohydrate, and that fat seems to play some part in the formation of young tissues which cannot be undertaken by any other nutritive constituent of food.¹ The association of rickets, especially, with a deficiency of fat in the diet seems to be pretty firmly established.

During the late war a large part of the population of Central Europe especially suffered from a great shortage of fat, the amount in the diet falling often as low as 20 grammes per day. In these regions diseased conditions characterized by generalized dropsy were widely prevalent, and have been ascribed to fat deficiency, although the reduction of the total food supply, and possibly also of some essential vitamin, may have played a part.²

It has also been found³ that the body works more economically upon carbohydrate than upon fat and with less fatigue, and that if fat largely predominates over carbohydrates in the food there is a wastage during severe work of nearly 11 per cent. of the energy contained in it. It would appear also that for the full utilization of carbohydrate a certain minimum of fat in the diet is necessary and conversely. There are, therefore, definite limits to the interchangeability of these nutritive constituents.

Another point in which fat is not able to replace carbohydrate in its dynamic equivalent is in protein-sparing power. In this direction 1 part of fat is not as efficient as $2\frac{1}{4}$ parts of carbohydrate.⁴ If, therefore, the proportion of fat in the diet be increased, the amount of protein consumed must also be increased. An examination of freely-chosen diets shows that this is actually done.

One may sum up in round numbers the standard amounts of the different nutritive constituents required daily thus:

Protein	..	..	..	..	..	100 grammes.
Carbohydrate	..	..	..	..	450	..
Fat	..	..	..	..	75	..

The energy value of such a diet is close upon 3,000 net Calories.

¹ See, for example, Cheadle, 'Artificial Feeding and Food Disorders of Infants' (London: Smith, Elder and Co.), p. 12.

² See Starling, 'The Significance of Fats in the Diet,' *Brit. Med. Journ.*, 1918, ii. 105.

³ Krogh and Lindhard, *Biochem. Journ.*, 1920, xiv. 290.

⁴ See Von Noorden, 'Pathologie des Stoffwechsels,' p. 117. Wicke and Weiske (*Zeits. f. physiol. Chemie*, 1895, xxi. 42, and 1896, xxii. 137) found that 100 grammes of starch diminished protein katabolism 19 to 21 per cent.; a similar weight of fat diminished it by 30 to 40 per cent.; i.e., the absolute effect of fat is greater than that of carb. hydrate, but the relative effect is less.

Such a standard may be regarded as suitable for a man of average build and weight, leading an active life and doing a fair amount of muscular work, and if a greater intake of energy is demanded, it should be met by increasing the amount of fat consumed.

In the following table I have collected similar standards fixed by others:¹

Authority.				Protein.	Fat.	Carbohydrate.	Calories.
Munk	..	..	..	105	56	500	3,022
Wolff	..	..	..	125	35	540	3,030
Voit	..	..	..	118	56	500	3,055
Rubner	..	..	..	127	52	509	3,092
Playfair	..	..	..	119	51	531	3,140
Moleschott	..	..	..	130	40	550	3,160
Atwater	..	..	..	125	125	450	3,520
Average				121	59	510	3,135

It will be observed that the chief point of divergence is in the relative proportion of carbohydrate and fat; the amount of protein is very similar in all. The total Calories yielded is remarkably constant, despite these divergencies. It should also be stated that in some of these standards no account is taken of the inevitable loss resulting from incomplete absorption of the constituents. To allow for this, the total Calories yielded would require to be increased by about 10 per cent., and about another 10 per cent. should be added to allow for the difference between the food as purchased and as eaten. In the latest American standard (Langworthy) the loss both from waste material in the food as purchased and from non-absorption is allowed for thus:

DIETARY STANDARD FOR MAN IN FULL VIGOUR AT
MODERATE MUSCULAR WORK.

								Protein.	Energy.
								Grammes.	Calories.
Food as purchased	..	..	..	..	..	..	..	115	3,800
Food eaten	..	..	..	..	..	..	..	100	3,500
Food digested	..	..	..	..	..	..	..	95	3,200

In such standards the ratio of protein to carbohydrates and fat taken together is of some importance. It is called the **nutritive ratio**. If 1 part of fat be counted as $2\frac{1}{2}$ parts of carbohydrate, the

¹ Chittenden's standard has not been included, but it may be taken as 60 grammes of protein, and a total fuel value of 2,800 Calories. He has not attempted to fix the proportion of fat and carbohydrate.

nutritive ratio in the average of the above standards is as 1 to 5.3. In this ratio we have an index of the proportion which the building material of the diet ought to bear to its purely energy-yielding constituents.

It need hardly be remarked that we do not consume our food in the form of pure protein, carbohydrate, and fat. If, therefore, the above conclusions are to be of any practical value, they must be translated into terms of ordinary articles of diet.

NECESSITY FOR A MIXED DIET.

In the first place it may be remarked that no one article of food contains the different nutritive constituents in proper proportions.

Some foods are too rich in protein; others contain too much carbohydrate or fat. The former statement is true of all animal foods, and, amongst the vegetable foods, of such articles as dried peas, beans, and lentils. Most other vegetable foods, on the contrary, of which bread and potatoes may be taken as types, contain an excess of carbohydrates.

The practical outcome of this is that a proper diet must be a mixed one, the excess of a particular element in one article being played off against its deficiency in another. People have found this out for themselves by experience; hence the popularity of such combinations as bread and cheese, bacon and beans, or potatoes and beef, in which the surplus of carbohydrate or fat in the first article is made up for by the excess of protein in the second. In a similar way we strike a proper balance in puddings by compounding them of articles rich in protein on the one hand, such as eggs and milk, with articles containing a surplus of carbohydrate on the other, such as rice or bread. The use of white sauce with fish is an example of a similar adaptation.

That mankind is right in so doing is borne out by the disastrous results which have followed attempts to live for any length of time on a single article of diet.

Hammond¹ tried to live on a daily ration of a pound and a half of starch, along with water. He had to abandon the experiment on the tenth day, owing to the onset of debility and fever. On another occasion he attempted to live on nothing but albumin. After nine days diarrhœa and albuminuria supervened, and the experiment had to be given up.

¹ 'Transactions of the American Medical Association, 1857,' x., p. 511. For similar experiments see Flint's 'Physiology of Man,' 1867, ii., p. 128.

The following table represents, with some modifications, standard daily dietaries constructed by Atwater :

STANDARD DIETARIES.

Daily Dietaries.—Food materials furnishing approximately the 0.28 pound (= 125 grammes) of protein and 3,500 Calories of energy of the standard for daily dietary of a man at moderate muscular work.

Food Materials.	Amount.	Cost.	NUTRITIVE CONSTITUENTS.				Fuel value.
			Total Organic Matter.	Protein.	Fats.	Carbo-hydrates.	
I.	Ounces.	s. d.	Pounds.	Pounds.	Pounds.	Pounds.	Calories.
Beef, round steak ..	13	0 6	'26	'14	'12	—	695
Butter	3	0 3	'16	—	'16	—	880
Potatoes	6	0 0½	'17	'02	—	'15	320
Bread	22	0 2½	'89	'12	'02	'75	1,760
	44	1 0	1'48	'28	'30	'90	3,455
II.							
Pork, salt	4	0 1½	'21	—	'21	—	880
Butter	2	0 2	'11	—	'11	—	450
Beans	16	0 2½	'84	'23	'02	'59	1,615
Bread	8	0 1	'33	'04	'01	'28	640
	30	0 7	1'49	'27	'35	'87	3,585
III.							
Beef, neck	10	0 2½	'19	'10	'09	—	550
Butter	1	0 1	'05	—	'05	—	225
Milk, 1 pint ..	16	0 2	'13	'04	'04	'05	325
Potatoes	16	0 1	'17	'02	—	'15	320
Oatmeal	4	0 1	'23	'04	'02	'17	460
Bread	16	0 2	'67	'09	'02	'56	1,280
Sugar	3	0 0½	'19	—	—	'19	345
	66	0 10	1'63	'29	'22	1'12	3,505
IV.							
Beef, upper shoulder	10	0 3½	'22	'09	'13	—	800
Ham	6	0 3	'19	'06	'13	—	650
Two eggs	3	0 2	'05	'03	'02	—	135
Butter	2	0 2	'11	—	'11	—	450
Milk, 1 pint ..	16	0 2	'13	'04	'04	'05	325
Potatoes	12	0 0½	'12	'01	—	'11	240
Flour	9	0 0½	'44	'05	'01	'38	825
Sugar	1	0 0½	'06	—	—	'06	115
	59	1 2½	1'32	'28	'44	'60	3,540
V.							
Sausage	4	0 1½	'14	'03	'11	—	510
Cod-fish	14	0 3½	'07	'07	—	—	140
Butter	2	0 2	'11	—	'11	—	450
Milk, 1 pint ..	16	0 2	'13	'04	'04	'05	325
Beans	5	0 0½	'26	'07	'01	'18	505
Rice	2	0 0½	'11	'01	—	'10	205
Potatoes	16	0 1	'24	'01	—	'23	420
Bread	9	0 1	'33	'04	'01	'28	640
Sugar	3	0 0½	'19	—	—	'19	345
	71	1 0½	1'58	'27	'28	1'03	3,540
VI.							
Beef	8	0 3	'18	'08	'10	—	560
Mackerel, salt	4	0 1½	'08	'04	'04	—	230
Two eggs	3	0 2	'05	'03	'02	—	135
Butter	2½	0 2½	'13	—	'13	—	505
Cheese	1	0 0½	'04	'02	'02	—	130
Milk, 1 pint ..	16	0 2	'13	'04	'04	'05	325
Potatoes	8	0 0½	'09	'01	—	'08	160
Rice	2	0 0½	'11	'01	—	'10	205
Bread	9	0 1	'38	'05	'01	'32	720
Sugar	1½	0 0½	'09	—	—	'09	175
	55	1 1½	1'88	28	'36	'64	3,205

The prices given in this table are those which rule in America. They are not always the same as those in this country, but the value of the figures is not really affected thereby.

It is worth while noticing, incidentally, the relative cost of these diets. Compare, for example, in this respect, No. II. with No. IV. Both of these contain practically the same amount of nutriment, but the latter costs exactly twice as much as the former. This is a fresh proof of the fact which has already been insisted upon, that the cost of a diet is no indication of its nutritive value.

The total weight of *dry* food which is consumed daily in such a standard diet as any of the above is about 23 ounces (or almost 1 ounce per hour). This represents 45 ounces (nearly 3 pounds) of ordinary food.

ACTUAL DIETARIES.

The standard dietaries given above are constructed, as we have seen, from theoretical data. It is interesting to compare with them the composition of the ordinary diets actually consumed by individuals of different countries and different social rank. In the following table (also modified from Atwater) a large number of such dietaries have been collected :

ACTUAL DIETARIES.

Classes.	NUTRITIVE CONSTITUENTS.				Potential Energy.
	Protein.	Fats.	Carbo-hydrates.	Total.	
	Grms.	Grms.	Grms.	Grms.	Calories
1. Sewing-girl, London, wages 3s. 9d. per week	53	33	316	402	1,820
2. Factory girl, Leipsic, Germany, wages 5s. per week	52	53	301	406	1,940
3. Weaver, England, time of scarcity	60	28	398	486	2,138
4. Labourers, Lombardy, Italy; diet mostly vegetable	82	40	362	484	2,192
5. Trappist monk in cloister; very little exercise, vegetable diet	68	11	469	548	2,304
6. Students, Japan	97	16	438	551	2,343
7. University professor, Munich, Germany; very little exercise	100	100	240	440	2,324
8. Lawyer, Munich	80	125	222	427	2,401
9. Physician, Munich	131	95	327	553	2,762
10. Painter, Leipsic, Germany	87	69	366	522	2,500
11. Cabinet-maker, Leipsic, Germany	77	57	466	600	2,757
12. 'Fully-fed' tailors, England	131	39	525	695	3,053
13. 'Well-paid' mechanic, Munich, Germany	151	54	479	684	3,085
14. Carpenter, Munich, Germany	131	68	494	693	3,194
15. 'Hard-worked' weaver, England	151	43	622	816	3,569
16. Blacksmith, England	176	71	667	914	4,117
17. Miners at very severe work, Germany	133	113	634	880	4,195
18. Brick-makers (Italians at contract work), Munich	167	117	675	959	4,641
19. Brewery labourer, Munich; very severe work, exceptional diet	223	113	909	1,245	5,692
20. German soldiers, peace footing	114	39	480	633	2,798
21. German soldiers, war footing	134	58	489	681	3,093
22. German soldiers, Franco-German War; extraordinary ration	157	285	331	773	4,652
23. Russian workmen	132	80	583	—	3,675
24. Swedish workmen (moderate labour)	134	79	523	—	3,436
25. Swedish workmen (hard labour)	189	110	714	—	4,726

ACTUAL DIETARIES—continued.

Classes.	NUTRITIVE CONSTITUENTS.				Potential Energy.
	Protein.	Fats.	Carbo-hydrates.	Total.	
	Grms.	Grms.	Grms.	Grms.	Calories
26. French Canadians, working people, in Canada	109	109	527	745	3,622
27. French Canadians, factory operatives, mechanics, etc., in Massachusetts	118	204	549	871	4,632
28. Other factory operatives, mechanics, etc., Massachusetts	127	186	531	844	4,428
29. Glass-blowers, East Cambridge, Mass.	95	132	481	708	3,590
30. Factory operatives, dressmakers, clerks, etc., boarding-house	114	150	522	786	4,002
31a. } Well-to-do private family, { food purchased	120	183	467	779	4,146
31b. } Connecticut { food eaten	128	177	466	771	4,082
32a. } College students from { food purchased	161	204	680	1,045	5,345
32b. } Northern and East- { food eaten	138	184	622	944	4,827
33a. } ern States; boarding- { food purchased	115	163	460	738	3,874
33b. } club, 2 dietaries of the { food eaten	104	136	421	661	3,417
33b. } same club					
34. College football team, food eaten	181	292	557	1,030	5,742
35. Machinist, Boston, Mass.	182	254	617	1,053	5,638
36. Brick-makers, Middletown, Conn.	222	263	758	1,243	6,464
37. Teamsters, marble-workers, etc., with hard work; Boston, Mass.	254	363	826	1,443	7,804
38. Brick-makers, Cambridge, Mass.	180	365	1,150	1,695	8,848
39. U.S. Army ration	120	161	454	735	3,851
40. U.S. Navy ration	143	184	520	847	4,998
41. Average of 53 American studies for different classes	103	138	436	677	3,500
42. Average diet of labourer's family in Edinburgh	107.7	88.4	479.4	675.5	3,228
43. Chinese dentist's family	115	113	289	—	2,705
44. Japanese professional man	63	3	481	—	2,258
45. Professional men in America (average of 14 studies)	104	125	423	—	3,325
46. Malays (professional men)	73	30	472	—	2,512
47. Europeans in Java (professional men)	100	84	264	—	2,470
48. University boat crews (average of 7 studies)	155	177	440	—	4,085
49. Average of 4 women students' clubs in America	101	139	414	—	3,405
50. Average of 16 men students' clubs in America	105	147	465	—	3,705
51. Average of 21 dietary studies amongst the labouring classes in Dublin	98.5	92.7	453.6	—	3,117
52. Average dietary of 5 halls of residence for students in Edinburgh	143	138	511	—	3,979
53. Dietary of a students' club in Finland ¹	157	191	380	—	3,984

On examining the table, it will be observed that, on the whole, the results conform very closely to the ideal standard already laid down. Here and there, however, one meets with divergences. Thus, the diet (No. 1) of the sewing-girl in London (which was investigated by Playfair) must be regarded as insufficient for the needs of health, while that of the well-to-do family in Connecticut (No. 31) is needlessly liberal. Taking the results as a whole, however, one is astonished at the closeness with which the actual corresponds to the ideal.

¹ Sundström, *Skand. Archiv f. Physiol.*, 1907, xix. 78.

APPLICATION OF THESE STANDARDS.

It must be clearly realized that such standard dietaries as those we have been considering have only a limited range of usefulness. They cannot be rigidly applied in any particular case, for they have only been drawn up to meet the needs of typical individuals living under known conditions, and doing a moderate amount of muscular work. They are of great value, however, in helping us to draw up rations for persons who have no free choice in their diet, and who are living under fairly uniform conditions (*e.g.*, soldiers and the inmates of prisons, workhouses, etc.), and as furnishing us with a standard by which to gauge the probable sufficiency or otherwise of the dietary which choice or necessity has imposed upon any section of the community. A good example of the application of such a standard in the former case is supplied by Dr. J. C. Dunlop's investigations into prison diets in Scotland.¹ Illustrations of its use in estimating the value of the diet in sections of the community have been furnished in this country by the investigations of Noel Paton and others into the diet of the labouring classes in Edinburgh,² those of Rowntree into that of the poorer sections of the community in York,³ of C. D. La Touche and T. T. Stafford in the case of working-class families in Dublin, and of Miss I. D. Cameron into the dietary in five students' halls of residence in Edinburgh.⁴ Very large use was also made of dietary standards in the construction of military and civilian rations in the course of the war.⁵ The results of these investigations will be referred to in the next chapter.

¹ Report to the Prison Commissioners for Scotland. London: P. S. King and Son, 1899.

² 'A Study of the Diet of the Labouring Classes in Edinburgh.' Edinburgh: Otto Schulze and Co.

³ 'Poverty: A Study of Town Life.' London: Macmillan and Co. New edition, 1903.

⁴ Proceedings of the Royal Society of Edinburgh, 1905-6, xxvi. 327.

⁵ Wood, 'The National Food Supply in Peace and War,' Cambridge University Press, 1917; Leonard Hill, 'Investigations of Workers' Food,' H.M. Stationery Office [Cd. 8370], 1916.

CHAPTER III

ON THE INFLUENCE OF VARIOUS CONDITIONS UPON THE
AMOUNT OF FOOD REQUIRED

I. WORK AND REST.

OF all the factors which affect the amount of food required, work and rest are by far the most potent. So much is this the case that all other influences are negligible in comparison. We shall consider the influence of **muscular work** first. We may accept the estimate of 100,000 kilogramme-metres (324 foot-tons) as representing a moderate amount of muscular work for one day, and the heat equivalent of this is 235 Calories. Seeing, however, that the human body can only transform about one-fifth of the energy supplied to it in the form of food into work, the remainder being dissipated as heat, it will be evident that more than 1,000 Calories of energy must be supplied as food in order to enable this amount of work to be done. Seeing, further, that the mere maintenance of the body requires a daily intake of about 2,000 Calories of energy, one arrives at the conclusion that the total daily energy value of the diet for a man doing a moderate amount of muscular work must be somewhere about 3,000 net Calories.

It should be observed, however, that the exact expenditure of energy required for the performance of any particular piece of work depends to a large degree upon the practice and training of the worker. An untrained worker is more extravagant in his output of energy for any given task than one who is more habituated to its performance, and much of the value of training depends upon the acquirement of the power of doing work with a minimum waste of effort, and of employing for it only those muscles which are really necessary.

The following are the estimates arrived at by the Food (War) Committee of the Royal Society for the intake required for different kinds of work:¹

¹ Report on the Food Requirements of Man. London: Harrison and Sons, March, 1919.

				<i>Energy Requirements.</i>		<i>Food Requirements.¹</i>
Tailor .. ..	..	..	..	2,500	Calories (net)	.. 2,750
Bookbinder .. ..	..	..	..	2,800	" "	.. 3,100
Shoemaker .. ..	..	..	..	2,850	" "	.. 3,150
Metal worker .. ..	..	..	..	3,200	" "	.. 3,500
Painter .. ..	..	..	..	3,250	" "	.. 3,600
Carpenter .. ..	..	..	..	3,200	" "	.. 3,500
Stonemason .. ..	..	..	..	4,400	" "	.. 4,850
Woodcutter .. ..	..	..	..	5,000	" "	.. 5,500

A reference to the table on p. 31 will show that even larger quantities than the last of these are sometimes actually consumed. Brickmakers, for example, whose occupation is one of the most laborious known, were found to take in food to the value of more than 8,000 Calories daily. On the other hand, a German doctor consumed less than 3,000 Calories, although medicine is by no means a sedentary occupation, while the consumption of a Trappist monk, living in the retirement of the cloister, amounted to hardly more than 2,000 Calories per day.

Atwater's American standards are as follows :

Man without muscular work .. ..	..	..	..	2,700	Calories.
Man with light muscular work .. ..	..	..	..	3,000	"
Man with moderate muscular work .. ..	..	..	..	3,500	"
Man with severe muscular work .. ..	..	..	..	4,500	"

The standards as estimated by various German authorities are as follows :²

				<i>Per Hour and Kilo.</i>	<i>Per Twenty-four Hours and Seventy Kilos.</i>
Maintenance .. ..	..	..	..	1	Calorie
In bed .. ..	..	..	..	1.25	Calories
Convalescent .. ..	..	..	..	1.5	"
House and office work .. ..	..	..	..	1.75	"
Light mechanical work .. ..	..	..	..	2	"

The standards determined by Lyon Playfair as long ago as 1865 work out in Calories thus :³

Subsistence diet .. ..	..	..	..	..	2,102	Calories.
Soldier (peace), light work .. ..	..	..	..	..	3,029	"
Soldier (war), moderate work .. ..	..	..	..	..	3,146	"
Royal Engineers, moderate work .. ..	..	..	..	..	3,818	"
Labourers, moderate work .. ..	..	..	..	..	3,611	"
Average for moderate work .. ..	..	..	..	..	3,525	"

Admitting that with an increase of work there must be a corresponding increase in the total amount of food consumed, the further question arises, In what form is the extra energy to be supplied? Should it be met by an increase of protein, of carbohydrate, or of fat, or should all be increased alike? In attempting to reply to this question, we enter the arena of much physiological controversy,

¹ Food requirements = energy requirements + 10 per cent. to allow for difference between food as utilised and food as purchased.

² *Deut. Med. Woch.*, 1919, 45, 369.

³ See 'A Study of the Diet of the Labouring Classes in Edinburgh,' by Noel Paton, J. C. Dunlop, and Elsie M. Inglis, p. 5. Edinburgh: Otto Schulze, 1901.

for, stated in another way, the problem to be solved is this: from what source do muscles derive the energy which enables them to do work?

In the earlier part of the last century most physiologists believed with Liebig that nitrogenous matter—in short, protein—was the muscle food *par excellence*. It was supposed that if much work had to be done, much protein must be supplied. Soon there arose another school, who contended, and backed their contention by incontrovertible experimental evidence, that, when hard muscular work is done, it is the carbonaceous, and not the nitrogenous, constituents of the body which suffer increased waste. Of the carbon-containing constituents of the food, the carbohydrates soon came to be regarded as the most valuable sources of muscle energy, a view in favour of which evidence is still accumulating (see p. 282). But, as often happens with the progress of knowledge, our views on this subject have tended to swing back a little, and now physiological opinion seems to have crystallized in a middle position, in which it may be said that a muscle is able to utilize *any* of the nutritive constituents of food for its work, but that, as long as there is a sufficiency of carbon-compounds present, these are preferred to the nitrogenous.¹

Direct observation of the diets actually selected by men engaged in severe toil confirms this conclusion. Diets Nos. 16, 17, 33 and 34, in the table (pp. 32, 33) may be taken as examples. It will be observed that in these *all* the nutritive constituents are increased, but that some have elected to consume the excess of carbon in the form of fat, others chiefly as carbohydrate. Both meet the requirements equally well, but carbohydrate has the advantage of being a cheaper source of supply. On the other hand, fat is less bulky, and those who can afford it do well to take in a large share of the increased energy they require in that form.

An increase of protein in the diet of toil is necessary, not so much to provide additional energy as to make good the increased wear and tear of muscle substance which the performance of hard work necessarily involves, as well as, in some cases at least, to enable the muscle to add to its bulk.

From an examination of such diets, the following standards have

¹ For experimental evidence leading to the same conclusion see Frentzel ('Ergographic Experiments upon the Restorative Effects of Various Nutritive Substances in Muscular Fatigue'), *Archiv für Anat. und Physiol.*, Sup. Bd., 1899, p. 141.

been constructed, which may serve as guides to the amount of each nutritive constituent required during the performance of hard labour :

<i>Authority.</i>	<i>Protein.</i>	<i>Fat.</i>	<i>Carbohydrate.</i>	<i>Calories.</i>
Voit	145	100	450	3,370
Rubner	165	70	565	3,644
Playfair	185	71	568	3,750
Atwater	150	150	500	4,060

The amount of protein allowed is in each case considerably above the average standard for moderate work (120 grammes). The sum of carbohydrate and fat is also raised, but in some cases the main increase has fallen upon the former, in others upon the latter. The subject under discussion has important bearings upon the diet of training.

Training may be described as a process by which the body is fitted to perform severe muscular feats.¹ The chief means by which one seeks to accomplish this object are the reduction of weight by the removal of superfluous water and fat, and the improvement of the tone of the muscles and heart, which produces endurance and long 'wind.' The first of these objects is attained by reducing the amount of fat in the diet, and by restricting the amount of fluid to that which is required to satisfy actual thirst. That the reduction of fluid in the body is physiologically justifiable is evident from the fact that a watery condition of the muscles and blood does not conduce to an energetic condition of body (see also p. 180). On the other hand, the opposite extreme should be avoided, for a too viscid condition of the blood is equally unfavourable.

No dietetic means have been consciously used to accomplish the second object—the improvement of the tone of the muscles and heart. Experience, however, seems to show that the results of these—*i.e.*, a gain in power of endurance and wind—are attained by increasing the amount of protein consumed, and in practice this takes the form of eating large quantities of meat. It may be asked if this increased consumption of protein can be defended on scientific grounds. To some extent, yes. Protein is the nutritive ingredient least likely to be converted into fat, and is also, on the whole, the most easily digested, and any disturbance of digestion seems to militate greatly against the accomplishment of the objects of training. Moreover, the hard exercise which is practised during training

¹ See also on this subject Clement Duke's 'School Diet,' chapter xi., 'The Diet in Training for School Games.'

involves a great deal of wear and tear in the muscles, and sometimes also an increase in their bulk, and both of these results must be provided for by an increased consumption of protein.

Further, also, in sudden and short muscular feats, such as those for which training is a preparation, what is required is a large output of energy for a short time. Protein, being a 'quick fuel,' is probably better adapted to secure this end than either carbohydrate or fat.¹ In recent years there has perhaps been a tendency to lay less stress on the use of meat, to recognise that in training, as in other conditions, the same diet does not suit all persons equally well, and to recommend, rather, the use of ordinary foods, taken in increased quantity, and with the avoidance of anything likely to produce indigestion, such as pastry and sweets. This is probably a move in the right direction; but one would like, on scientific grounds, to see sugar more largely tried.

The tendency would still seem to be to eat too much and at too long intervals. 'He that striveth for the mastery,' says the Apostle, 'is temperate in all things.' And this applies to diet as well as to everything else.

The chief scientific studies of the dietaries of persons engaged in athletic exercises have been made in America.²

One of these concerns the diet of Sandow, 'the strong man,' and is on that account of some special interest. We read that: 'Mr. Sandow does not follow any prescribed diet, but eats whatever he desires, always being careful to eat less than he craves rather than more. He eats very slowly. . . . Sometimes he takes a cup of weak tea and a little bread in the morning, but usually his first meal is eaten about noon. He eats again about six o'clock, and again about midnight, after his exhibition of feats of strength is over. He smokes a good deal, and drinks beer and other alcoholic beverages.'

'The total amount of food consumed,' says the writer, 'is rather more than the average, though in his own opinion Mr. Sandow is not a large eater. This is in accord with the general conclusion reached in many investigations made with labouring men, that severe muscular exercise requires an abundant diet.'

¹ It is also beginning to be believed by some physiologists that work which causes a high degree of nervous and mental strain demands for its performance a larger supply of protein than the same amount of labour carried out in a more leisurely manner and under less pressure.

² Langworthy and Beal, Storr's Agricultural Experiment Station, Ninth Annual Report, part ii., 1896.

The following table represents, approximately, Sandow's diet for one day :

Date.	Food Consumed. (Quantities in Ounces.)	NUTRIENTS.			Potential Energy.	Nutritive Ratio.
		Protein.	Fat.	Carbo- hydrates.		
Jan. 10.		lb.	lb.	lb.	Calories.	1:
Dinner	2 oysters, 10 soup, 1 celery, 3 fish, 1 potatoes, 2 oyster plant, 1 green peas, 1 tomatoes, 2 bread, 2 roast beef, 2½ chicken, 4 ice cream, 3 orange sherbet, ½ cakes, 1 butter, 11 wine (Burgundy) ..	•17	•14	•34		
Supper	8 roast beef, 7½ rye bread, 3½ Cam- embert cheese, 2 water biscuit, 3½ cakes, 4¼ lb. beer¹	•26	•14	•61		
Jan. 11.						
Break- fast²	9 vegetable soup, 2 potatoes, 3 veal (breaded chop), ½ green peas, 2 roast beef, 4½ bread pudding, ½ cakes, 14 beer	•11	•05	•16		
	Total in pounds	•54	•33	1•11	4,462	3•4
	Total in grammes	244	151	502		

The average composition of the diet consumed by some University boat crews in America was as follows:³

Protein	155 grammes	} = 4,085 Calories.
Fat	177 "	
Carbohydrates ..	440 "	

Two studies of the diet of college football teams yielded the following results:⁴

No. 1.	No. 2.
Protein .. 181 grms. } = 5,740	Protein .. 270 grms. } = 7,885
Fat 292 " } Calories.	Fat 416 " } Calories.
Carbohydrates 557 " }	Carbohydrates 710 " }

An investigation of the diets of two Scandinavian professional athletes resulted as follows:⁵

No. 1.	No. 2.
Protein .. 217 grms. } = 5,070	Protein .. 182 grms. } = 4,254
Fat 259 " } Calories.	Fat 204 " } Calories.
Carbohydrates 431 " }	Carbohydrates 392 " }

The most striking points about the above dietaries of athletes are (1) the large amount of total energy which they contain, and (2) their

¹ Sandow sat a long time with friends after supper, and consumed a large part of the beer during this time.

² This was the regular meal served at the hotel.

³ 'Dietary Studies of University Boat Crews,' Bull. No. 75, United States Department of Agriculture, Office of Experiment Stations, 1900, p. 66.

⁴ *Ibid.*

⁵ Lavonius, *Skand. Archiv f. Physiol.*, 1905, Bd. xvii., 196.

richness in protein, the former being about 15 per cent., and the latter 25 per cent., above the standard for moderate muscular work. It seems reasonable to suppose that these peculiarities are a response to the physiological demands which athletic contests make upon the body, and that the diet of training should be one yielding a large amount of energy and containing a relatively high proportion of protein.

Mental work influences the amount and nature of the food required in a very different way from muscular labour. The first thing which it is important to realize clearly is that brain work does not appreciably increase bodily waste. On this point all exact experiments agree. One of the most careful of these is recorded by Atwater.¹ A man was confined in a respiration calorimeter for a number of days, and on certain of them he engaged in the severe mental work of reading a German treatise on physics. The subject of the experiment, it may be added, was an intelligent person, who fully understood the nature of the experiment, and did not shirk mental application. It was found that on the working days bodily waste was no greater than during rest.

The next point to get hold of is that *there is no special brain food*. Büchner gave utterance to the dictum, 'Without phosphorus there is no thought.' This is only true in the sense that the brain contains phosphorus, and without the brain, thought, as we know it, is unthinkable. But it has never been shown that an increased supply of phosphorus in the food is specially favourable to mental effort, nor, indeed, has that been proved for any other food.² It requires, of course, no special demonstration that an ill-nourished brain is not one from which good work can be expected: for the brain, like every other organ, demands for its work an abundant supply of healthy blood, and there is, perhaps, no part of the body which is more sensitive to any impoverishment of that fluid. On the other hand, any oversupply of food must be equally unfavourable to mental work. A large amount of food implies a large amount of work on the part of

¹ United States Department of Agriculture, Bull. 44, 1897. For later experiments, which also tended to show that mental effort has no positive influence on metabolism, see United States Department of Agriculture, Office of Experiment Stations, Bull. 208, 1909.

² Mairet and Florence (abstract in *Brit. Med. Journ.*, 1907, ii. 539) have shown by experiment that during intellectual labour the amounts of nitrogen and phosphoric acid absorbed from the alimentary canal are diminished, as compared with the period of repose, either following or preceding the spell of mental work, and that appreciably more phosphorus is eliminated during mental work than is absorbed in the same time. These results, however, might be explained by an adverse influence exerted by hard mental labour on the processes of digestion and absorption.

the digestive organs, and that, in its turn, implies a large expenditure of nervous energy and blood. But if more blood is required in the abdomen, there must be less left for the brain, and the activity of the latter declines, as is evidenced by the feeling of lethargy which is familiar to everyone after a large meal. It comes, then, to this, that *the digestibility of a food is of far greater concern to a brain worker than its chemical composition*. Small and rather frequent meals of easily-digested food is the ideal to aim at. The necessity for this is the more apparent when one remembers that brain work is usually also sedentary work. Compared with the diet of muscular labour, therefore, the diet for mental work should be small. The reduction should probably affect carbohydrates and fats more than protein, for it is the two former, as we have seen, which tend to be specially made use of as muscle foods. The protein consumed should be derived to a large extent from animal foods, for these are its most compact and digestible source. Hence it is that it is far easier for a man who is performing bodily labour to be a vegetarian, than for one who is engaged in mental work. Whether an abundant supply of protein has, *per se*, an actually stimulating influence on the brain must be left undecided, though such a view is not without its supporters.¹

Rest, as might be expected, influences the amount of food required in a precisely opposite direction to muscular work. Much less food is required in the former condition than in the latter. The reduction, however, should not affect all the nutritive constituents equally. Even when the body is in complete repose there is still wear and tear of its substance going on. Such waste, indeed, is inevitable, for it is an invariable accompaniment of even passive life, and one finds that during rest the excretion of carbonic acid is much more profoundly influenced than that of nitrogen. The practical result is that in the diet of repose the carbohydrates and fats should be relatively more restricted than the proteins. The energy value of such a diet may even fall to 2,000 Calories or less, and yet prove sufficient for the bodily needs. This is a fact of great value in therapeutics. It explains why it is that one has so much less difficulty in fattening a patient when at rest in bed than when up and about; for the former condition the demand both for heat and energy is enormously lessened. Sleep intensifies the benefits of rest by insuring more absolute relaxation of the muscles, and also seems in itself to lessen somewhat the waste of fat. A German writer (Lobisch) goes so far as to assert that an extra hour's sleep at night is equivalent to a saving of $2\frac{1}{2}$ pounds of fat in a year.

¹ See Roberts, 'Digestion and Diet,' p. 109.

2. INFLUENCE OF WEIGHT AND BUILD.

The heavier the body—*i.e.*, the greater the number of cells which it contains—the greater is the amount of food required for its maintenance. This is true as a general statement, but in practice the *kind* of cell which is increased must also be considered. The nutritive requirements of a pound of bone, a pound of fat, and a pound of muscle are very different. Fat and bone are, so to speak, dead tissues. Their vital activity is but slight, their daily wear and tear small. Muscle, on the other hand, is a highly active tissue constantly breaking down, and requiring not merely much protein to repair its waste, but making frequent demands on the carbonaceous foods to provide it with a supply of energy.¹ Thus it is that a man whose weight is mainly due to muscle will require relatively more, and especially more nitrogenous, food than one who owes his weight to the size of his bones or to a substantial covering of fat. Taking the average man, however, the following estimate of the number of Calories required for every kilo of body-weight in different circumstances will be found to hold good:

					Calories per Kilo. (2·2 pounds).
In bed	..	..	..	..	30 to 34
Up, but doing no work	..	..	..	..	34 to 40
At moderate muscular work	..	..	..	..	40 to 45
At hard muscular work	..	..	..	..	45 to 60

On the other hand, and for the reason given above, 26 to 36 Calories per kilo will probably suffice for a man who is very stout.

Rubner² gives the following estimates of the amount of energy and

¹ Dr. Smith (*Lancet*, May 21, 1864) gives the amount of fat consumed under different conditions as follows:

One hour of lying asleep consumes	..	..	..	0·31 ounce.
" " lying awake	"	..	..	0·46 "
" " standing	"	..	..	0·55 "
" " walking at two miles per hour consumes				1·1 ounces.
" " " three " "				1·6 "
" " work on a treadmill consumes				2·75 "

Ranke compared the output of two men of equal weight, one fat, the other muscular, and both fasting, with the following results:

				Muscular Man.	Fat Man.
Protein	..	..	78	50	
Fat	..	..	215	204	

² Leyden's 'Handbuch der Ernährungstherapie und Diätetik,' 2nd ed., vol. i., p. 153, 1903.

protein required by persons of different weight in the same circumstances :

LIGHT WORK.						MODERATE WORK.					
Weight. st. lb.			Calories.		Grammes Protein.	Weight. st. lb.			Calories.		Grammes Protein.
11	6	..	2,864	..	134	11	6	..	3,372	..	128
10	0	..	2,631	..	123	10	0	..	3,094	..	118
9	8	..	2,368	..	111	9	8	..	3,792	..	106
7	2	...	2,102	..	90	7	2	..	2,472	..	96
5	10	...	1,810	...	84	5	10	..	2,129	..	81

The build or shape of the body is of even greater importance in this connection than its actual weight. Further, we may say that the question of build and shape, as far as the amount of food required is concerned, resolves itself into a question of surface. The larger the surface of the body relative to its bulk, the greater is the amount of heat lost by radiation, and the greater the amount of food required to maintain its temperature. A reference to the accompanying diagram (Fig. 2) will make this clear. Let us suppose that we have two bodies, the first being 9 feet high, 3 feet broad, and 1 foot thick, and the second measuring 3 feet in every dimension. Both will have a cubic content of 27 feet, but the first will have a surface of 78 square feet, the second of only 54 square feet; in other words, the surface exposed is almost one-third greater in the one case than in the other, and the amount of heat lost will also be proportionately greater. The first of these figures would represent the condition of a tall, thin man, the second that of a short, stout man; and as the former must lose about one-third more heat than the latter, he will obviously require about one-third more fuel in the form of food if the temperature of the

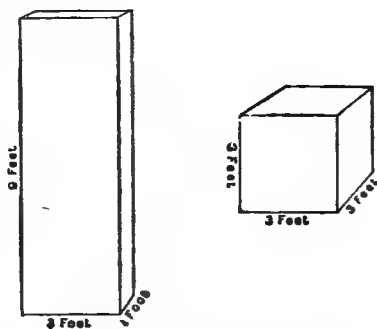


FIG. 2.—TO ILLUSTRATE THE INFLUENCE OF SHAPE ON EXTENT OF SURFACE.

two is to remain equal. This explains the apparent paradox, which is otherwise apt to prove rather puzzling, that a thin man often eats considerably more food than a fat man, yet the former remains lean and the latter becomes more and more stout. The former really needs more food simply because he is thin; while the fatter a man becomes, the less food does he require, for with every increase in bulk there is a corresponding diminution in the relative amount of surface exposed. When one estimates the amount of

Calories required from the point of view of surface rather than of mass (body-weight), it is remarkable how uniform the requirement is for all persons living under the same external conditions. The extent of body-surface in an average man is about $21\frac{1}{2}$ square feet, and for every $10\frac{3}{4}$ square feet about 1,500 Calories must be supplied daily.

3. INFLUENCE OF AGE AND SEX.

It seems to be a general principle in biology, that the younger the cell the greater is its power of oxidizing and breaking down food, and that the older it is the less of this power does it possess; in other words, what the cells of the body gain by multiplication they lose in individual activity. In accordance with this principle, the assimilative powers of a child are greater than those of an adult, and those of the latter greater than those of an old man. The child, therefore, relatively to its weight, will require the greater amount of food.

Two other considerations emphasize this necessity. Like all small animals, a child has a large surface in proportion to its bulk, and that means, as we have just seen, a relatively great heat loss. Further, a child is a *growing* animal; it has not merely to keep its tissues in repair, but has to go on adding to them, and that necessitates a relatively abundant supply of building material.¹

The practical results of these considerations will be more fully dealt with in another chapter (Chapter XXIV.), but they have led to the following calculations regarding the total amount of food required at different ages as compared with the needs of a fully-grown man.²

FOOD REQUIREMENTS AT VARIOUS AGES COMPARED WITH THOSE OF THE
'AVERAGE MAN.'

<i>Both Sexes.</i>						<i>Coefficients.</i>	<i>Utilisable Calories.</i>
0-6	..	..	..	..	..	0'5	1,500
6-10	..	..	..	..	..	0'6	1,800
10-13	..	..	..	..	..	0'83	2,500
13-20 (boys)	..	..	..	..	..	1'0	3,000
Average man	..	..	..	..	..	1'0	3,000
13-20 (girls)	..	..	..	..	..	0'83	2,500
Average woman	..	..	..	..	..	0'83	2,500

¹ It must be remembered that during the period of active growth only a small fraction of the increased amount of food taken in is actually stored up in the body, the rest being broken down, and increasing thereby the general metabolism. For a full discussion of this point see Rubner's 'Beiträge zur Ernährung im Knabenalter' (Berlin: Hirschwald, 1902).

² Food (War) Committee Report, *loc. cit.* See also Benedict, 'Energy Requirements of Children from Birth to Puberty' (*Boston Med. and Surg. Journ.*, 1919, 181, 107).

The relatively large amount of food required by the adolescent boy and girl should be noted; some authorities even go so far as to say that the intake at this period of life should be greater than that of a full-grown man doing moderate work.

The dietetic requirements of old age are just the reverse of those of childhood. The assimilative power of the cells is on the wane¹ and the bodily activities are restricted, hence less food is required. The danger of overfeeding the old is almost as great as that of underfeeding the young; an excess of nourishment chokes instead of feeding the flickering flame of life. Leanness and longevity, it has been remarked, go together, and a man will only roll all the faster down the hill of life if his figure be rotund. 'Discerne,' says Bacon, 'of the coming on of yeares, and thinke not to doe the same things still, for Age will not be defied,' and one cannot with impunity continue to 'do the same things' in matters of diet any more than in anything else.

Forster made some exact investigations into the diet of healthy old persons, and found that it contained the following amounts of nutritive constituents:

	<i>Protein.</i>	<i>Fat.</i>	<i>Carbohydrates.</i>	<i>Calories.</i>
Men	92	45	332	2,149
Women.. ..	80	49	266	1,875

The results fully bear out the above contentions.² In the following diagram (Fig. 3) the amount of each nutritive constituent required at different periods of life is represented. While the figures must not be regarded as in any sense absolute, they serve to represent in a graphic way the relative requirements of different ages.

Luigi Cornaro is one of the most eloquent advocates of temperance in old age. 'It cannot be urged too often,' he writes,³ 'that when the Natural Heat begins to decay 'tis necessary for the preservation of health to abate the quantity of what one eats and drinks every Day; Nature requiring but very little for the Support of the Life of Man, especially that of an Old Man.' He tells us that he ate only 12 ounces of solid food daily, consisting chiefly of bread, wine, broths and eggs, veal, mutton, partridges, chicken, and pigeons, and some kinds of fish, such as pike, for 'all of these aliments,' he adds, 'are proper for old men.' His system was certainly justified by its results, for he is said to have lived to be a hundred years old.

¹ Von Limbeck, 'Zur Lehre vom Stoffwechsel im Greisenalter, *Zeits. für Klin. Med.*, 1894, xxvi. 437. See also Sir Henry Thompson's 'Diet in Relation to Age and Activity' for a practical discussion on the subject.

² For further studies of the diet in old age see United States Department of Agriculture, Office of Experiment Stations, Bull. 223, 1910.

³ 'Sure and Certain Methods of Attaining a Long and Healthful Life,' translated from the fourth edition; London. 1727, p. 91.

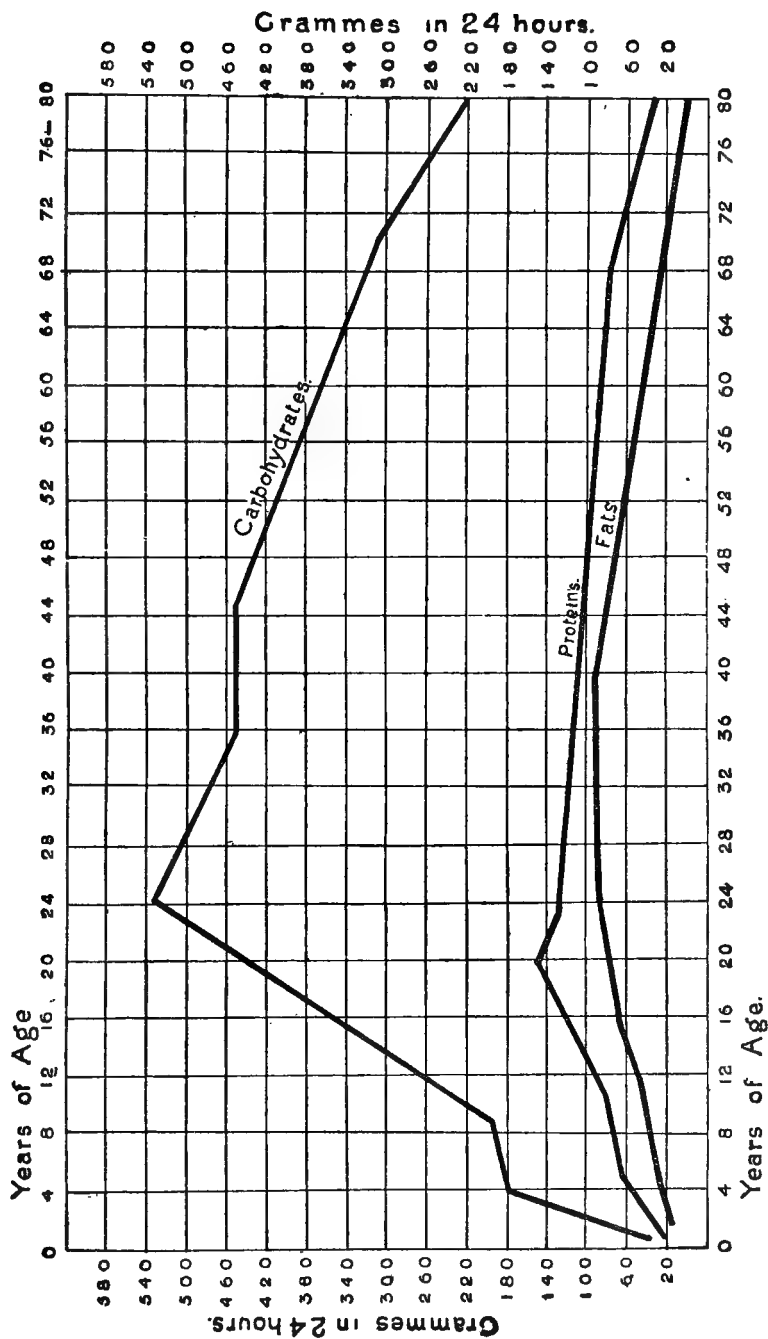


FIG. 3.—NUTRITIVE REQUIREMENTS AT DIFFERENT AGES.

Women require less food than men, for their bodies are not only, as a rule, of less weight, but are relatively richer in fat and poorer in muscle than those of the latter. Further, there is a considerable amount of evidence for the belief that the cells of the body are less able to carry out oxidation changes in the female than in the male; or, in physiological language, that the tendency of metabolism is in the direction of a preponderance of anabolism in the one case, and of katabolism in the other. Upon this supposition a whole theory of sex differences has been based.¹ Whether this be so or not, there can be no doubt that the diet of the female should be less in amount than that of the male; and it has been estimated that, if a man consumes 10 parts of food, a woman under similar conditions should require only 8 parts.² Expressed in terms of nutritive constituents and Calories, the diet of an average woman doing a moderate amount of muscular work should be as follows:

<i>Protein.</i>	<i>Fat.</i>	<i>Carbohydrates.</i>	<i>Calories (utilisable).</i>
90	40	400	2,381

The proportions in a condition of rest would be:

Protein	..	..	..	85
Fat	..	..	..	40
Carbohydrates	..	..	..	320

yielding about 2,000 Calories of energy. When one considers the relative requirements of the two sexes, it is not surprising that some of the most aggravated cases of obesity should be met with in women of luxurious life.

4. INFLUENCE OF CLIMATE AND SEASON.

The influence of climate, and especially of a warm climate, on the amount of food required is commonly exaggerated. It seems natural to suppose that, if the surrounding temperature is high, the amount of heat required to be produced in the body will be less. But this is to lose sight of the fact that the temperature of the body is chiefly regulated by *physical*, and not by *chemical*, means. To put it more plainly, we adjust the temperature of our bodies to that of the surrounding medium, not so much by the expensive method of increasing or diminishing the amount of heat we produce, as by the simpler expedient of regulating the amount of heat lost.

Heat and life, as has been already pointed out, are inseparable. We cannot help producing a certain amount of heat if we are to go on living at all. Now, thanks to the fact that we wear clothes, our bodies live in an atmosphere of about 90° Fahr.—that is

¹ Geddes and Thompson, 'Evolution of Sex,' 1889.

² During pregnancy, however, the diet should be more abundant,

to say, in what is practically a tropical climate. At this temperature the amount of heat produced in the body is in excess of its requirements, even when that production is as small as is compatible with the full activity of our cells. This means that, even in a temperature of 90°, we are constantly wasting a certain amount of heat. Suppose, now, that one goes into the tropical regions. As the external temperature rises, the amount of heat which the body requires becomes less and less; but already as little is being produced as is compatible with health, so that, in order to adjust the balance, one must not try to diminish the production by eating less food, but rather to increase the loss by wearing thinner clothes. In harmony with this, one finds, as a matter of fact, that the consumption of food by the inhabitants of the tropics is not notably less than that of those who live in the temperate zone.¹

Suppose, on the other hand, that one moves from a temperate to a colder latitude. The body will now require more heat to keep its temperature up to the normal level, and the first method had recourse to in order to meet the increased demand is by economizing waste, or, in other words, by diminishing the amount of heat lost. In practice, this is accomplished by an increase of clothing. If the external temperature falls still further, however, this method by itself becomes inadequate, and steps must be taken to increase heat production; it is only then that it becomes advisable to consume more food.

‘During the whole of our march,’ says Sir John Franklin, in describing his journeyings in the Arctic regions, ‘we experienced that no quantity of clothing could keep us warm while we fasted, but on those occasions on which we were enabled to go to bed with full stomachs we passed the night in a warm and comfortable manner.’ Translated into physiological language, this means that the demand for heat in the body was so great that it could no longer be met by diminishing loss, but that the deficit had to be made up by an increase of heat production—*i.e.*, by a greater consumption of food.

What form the increased consumption of food takes is, comparatively speaking, of little moment. All that is really necessary is that the number of Calories which the diet is capable of yielding should be considerably raised. As a matter of convenience, however, and in order to avoid overfilling the stomach, it is best to have

¹ It would seem, however, that the diet of tropical dwellers usually contains relatively less protein and fat and more carbohydrates, especially sugar, than that of the inhabitants of colder regions. See a paper by Harvey W. Wiley, *Med. News*, 1904, lxxv. 945. There is some reason, also, to believe that in hot weather and in warm climates the digestive capacity is not so great as in colder, and that large quantities of food are consequently not so well borne.

recourse to fat as the principal source of the extra heat required, for fat is the compactest form of fuel we possess. Carbohydrates would serve the purpose equally well as far as the cells of the body are concerned, but one would require to consume more than twice as much of them as of fat in order to obtain the same amount of heat. Besides, in very cold latitudes carbohydrates are not so easily obtained as fat. This is the explanation of the enormous quantities of blubber which the Esquimaux consumes, as much as 20 pounds of flesh and blubber, we are credibly informed, being eaten in the course of a day in some cases. A similar adaptation to circumstances on the part of Nature is seen in the milk of the walrus, which contains 40 per cent. of fat, thus supplying the young with an abundant and compact source of fuel, and enabling them to maintain their temperature in the icy waters of the North.

The influence of season on the amount of food required is similar in kind to the influence of climate, though less in degree. In summer clothing should be diminished rather than food; in winter warmer clothing should be worn, but the amount of food, and especially the proportion of fat which it contains, may with advantage be increased.¹

Ranke found² that in order to keep his body-weight constant he had to eat as much food in summer as in winter. In the hot weather, however, the inclination to eat was less, and if he followed his appetite the fuel value of his diet fell by as much as 400 Calories per day. If, on the other hand, he disregarded his inclinations and ate enough to maintain his body-weight, his health suffered, a result which he attributes to an over-production of heat in the body. It would seem to follow from this that a slight loss of weight during the summer months is inevitable. Hirschfeld, criticising these results,³ is inclined to attribute the bad effects which Ranke observed to follow the adoption of a full diet in hot weather to an over-consumption of protein rather than to the richness of the diet as a whole. It certainly seems reasonable to avoid in warm weather what have already been described as the 'quick fuels'—*i.e.*, those nutritive constituents from which a large amount of heat can be produced in a short time, especially the proteins.⁴ For this reason, as

¹ It has been estimated that 800 Calories more of energy are required in winter than in summer.

² 'Der Nahrungsbedarf im Winter und Sommer des gemässigten Klima' (*Zeit. f. Biologie*, 1900, xl. 288).

³ 'Ueber Ernährung in der heissen Jahreszeit und im Warmen Klima' (*Deut. Med. Woch.*, 1902, xxviii. 674).

⁴ Protein is not only in itself a source of heat, but it acts as a stimulant to metabolism, thus increasing general heat production in the body as well. Hence, persons who live on minimal amounts of protein are apt to be very sensitive to cold

well as on account of the fact that they are relatively rich in fat, the animal foods should be more sparingly consumed in summer, and the proportion of vegetable matters in the diet relatively increased.

5. INFLUENCE OF PERSONAL PECULIARITY.

There is a widespread impression that some people can 'get on' with less food than others, even although they are living under identical external conditions. We hear it said of one man that he is always eating, and yet remains thin and languid; of another, that he lives the life of an ascetic, and yet grows hearty and fat.

To a large extent these apparent results are explicable by the differences of weight, build, and shape of body, which we have already studied; but even giving such considerations their full weight, there remains some room for the belief that some people really do make better use of their food than others. To use a popular phrase, they 'put it into a better skin.' Scientific evidence on this point is very difficult to obtain. Remembering, however, that the utilization of food is a function of living protoplasm, it is at least conceivable that in some persons the activity of the cells is greater than in others, and leads to a more rapid breaking down of food and a greater waste of heat.¹ It has been clearly proved by scientific experiment that a man who is skilled through long practice in doing any particular piece of muscular work will do it with less expenditure of bodily material, as expressed in the excretion of carbonic acid and nitrogen, than a novice. In other words, and as far as that particular kind of work is concerned, the former is a more economical machine than the latter, and there is really no very apparent reason why there should not be degrees of such economy in the performance of all the functions essential to life.

The influence of the nervous system in regulating tissue waste must also be borne in mind. The functions of nutrition and assimilation seem in some mysterious way to be under the dominion of the central nervous system, and if the control so exercised is diminished there may be a tendency to increased waste of tissue, just as there is in a paralysed limb. But the degree in which the nervous system exercises its functions differs enormously in different persons, and so it is not altogether incredible that the degree in which bodily waste is controlled may differ also.

Be this as it may, there is no more practical fact in dietetics than the different results which the same food, either in quantity or in kind, produces in different persons, and it has to be constantly borne

¹ For a criticism of this view see Rubner's 'Beiträge zur Ernährung im Knabenalter' (Berlin, 1902).

in mind in regulating the diet of the sick. A study of the habits of different nationalities reveals the same thing. The German is notoriously a larger feeder than the Frenchman, and Americans seem to consume more food per head than Englishmen in the same conditions of life. Even granting, which might be disputed, that the output of work and energy is greater per individual in America than in Europe, the difference is not entirely explained, and may perhaps rest on some inherent constitutional cause. Anyhow, a consideration of facts such as these should warn one of the dangers of dogmatism in matters of diet. We can and may lay down rules as to the kind and amount of food required under different circumstances, but we are treading on dangerous ground when we come to apply these rules to individual cases. In the matter of diet every man must, in the last resort, be a law unto himself; but he should draw up his dietetic code intelligently, and apply it honestly, giving due heed to the warnings which Nature is sure to address to him should he at any time transgress.

Having considered the kind and quantity of food required in health, and the way in which these are affected by various bodily conditions and states of life, we may now glance for a moment at the general effects of an excessive or a deficient supply of food respectively.

Overfeeding.—It is, perhaps, no exaggeration to say that the tendency of civilized peoples, and especially of the upper classes in civilized society, is to eat too much. Feeding is pleasurable as well as necessary, and when the necessities of the body have been supplied, the process is apt to be continued merely for the sake of the pleasure which it affords. Now, a moderate excess of food is probably harmless, if not actually beneficial. It is not safe to sail too near the wind in matters of diet. As a French writer has paradoxically put it: ‘*Pour avoir assez il faut avoir trop.*’ For it is well to have some reserve in the body which can be called upon if one is compelled for any reason to go for some time without any food at all. The presence of such a reserve can only be insured by the habitual consumption of rather more food than is required to meet the bare necessities of the body. It is in this way, too, that the occasional indulgence in an unusually heavy meal can be justified. There are some, for instance, who see in the large Sunday dinner of the workman a partial provision for the wants of the whole week.

Leaving aside the consideration of this surplus, which can hardly be described as an excess, one has to look at the results of acute and

chronic overfeeding separately. The injurious effects of consuming a great excess of food at one time are local rather than remote. They fall chiefly upon the digestive organs. The overburdened stomach may relieve itself by vomiting, or, if the food is passed on into the intestine, it is apt to undergo decomposition before it is all absorbed, and be carried off by diarrhœa. That these effects may sometimes be sufficiently severe is evidenced by the fact that people have been known to die of a 'surfeit,' though in modern days such a result must be regarded as very rare, always excepting those instances in which even moderate overloading of the stomach may have too much hampered the action of a feeble heart.

If the process of absorption goes on too rapidly for assimilation to keep pace with it, the blood seems to be able to rid itself of some, at least, of the surplus products of digestion by aid of the kidneys. Thus, a great excess of protein in the food may give rise to transient albuminuria, while sugar may temporarily appear in the urine after an extravagant consumption of carbohydrates. This method of adjusting the balance, however, seems to be one which is but seldom had recourse to.

The general results of habitual or chronic overfeeding are more insidious, and seem to vary with the nutritive ingredient which is specially indulged in. If this be carbohydrate or fat, the surplus is simply stored up in the form of fat, and obesity results. In the case of protein such storage is hardly possible, for so great is the tendency of 'nitrogenous equilibrium' to assert itself that the body can only 'lay on' protein for very short periods, unless the process of growth is still going on. What usually appears to happen is that the surplus protein is split up into two portions, one of which contains most of the carbon and is probably converted into fat and stored in that form, while the nitrogen-containing part is broken down, but not, perhaps, very rapidly and completely; so that the products which represent the intermediate steps in its destruction circulate for some time in the blood before being excreted in the form of urea. It may be that some of these products are concerned in the production of such conditions as granular degeneration of the kidneys, high arterial tension, gout, and rheumatism; but that is a point on which it is not yet advisable to speak very dogmatically. It must be remembered, too, in this connection that an excess of protein spares in the blood may produce very similar results to an excess of protein itself by shielding the latter from complete and rapid oxidation.

Underfeeding.—It is astonishing how long the body can go without

food provided a due supply of water is obtainable. Lunatics have been known to refuse food for four or five weeks at a stretch, and the experience of professional fasters shows that long periods of starvation can be borne with impunity. Experiment, indeed, has shown that it is only when the weight of the body has fallen to one-half or one-third its original amount that death from inanition ensues. It is well to remember these facts when dealing with cases of acute disease. A doctor is very apt to flatter himself that he is keeping a patient alive by rectal feeding, for example, when all the time the patient is really living on his own tissues. Nor need one be unduly alarmed if a well-nourished patient is unable to take any food at all for a few days. His own reserves will be able to tide him over the emergency without much injury.

Of chronic or habitual underfeeding as a whole it may safely be said that it is more injurious than the opposite condition of intemperance in food. One has to recognize also that a relative lack of one nutritive constituent is probably commoner than a deficiency of all, or, in other words, that an *ill-balanced diet* is more frequently met with than one which is defective all round. As nitrogen is the element of which the body is mainly built up, a lack of protein in the food seems to be more injurious than a shortcoming in respect of carbohydrate or fat. As this point has already been referred to (p. 24), it need only be repeated here that an insufficient supply of protein leads to imperfect tissue repair, more especially, perhaps, of the muscles and blood;¹ that it causes the body to become unduly watery, whence the pallor and puffiness of the underfed; and that the combined effect of these results is to produce a lowering of the power of resistance to unfavourable influences, including disease.²

It must be observed, however, that experience in the war has shown that it is possible for life to be maintained and normal work carried out on a diet very much less than that to which the individual has been accustomed.

The first effect of diminution of food is a diminution in the weight of the body. The individual, if he remains at his work, puts out at first the same amount of energy as before, the energy lacking from the food being supplied in the first place by the fat and in the second place by the muscular tissues of the body. But when under this regime the weight has fallen 10 per cent. to 12 per cent., it is found that the basal requirements of the individual are largely reduced. Thus in one case where a man 5 feet 2 inches on semi-starvation diminished in weight from 115 pounds to 84 pounds, his basal metabolism was diminished from 40.5 to 33 Calories per square metre of body surface. In another case, of a man 6 feet 2 inches, where the loss of weight was still larger, viz., 163 pounds to 101 pounds, there was a diminution of basal metabolism from 40 to 25.4 Calories per square metre body surface. Under these conditions all the processes of the body are carried out more economically. There is no diminution in the actual expenditure of energy required for doing a certain amount of work, but the basal metabolism is diminished and the individual is more economical in effort and

¹ For experimental evidence, see Subbotin, *Zeitsch. für Biologie*, 1871, vii., p. 185.

² For information on the part played by habitual underfeeding in the production of physical deterioration, see evidence by the writer and others in the Report of the Interdepartmental Committee on Physical Deterioration (London: Eyre and Spottiswoode, 1904).

economizes his muscular activity to the utmost possible extent. Thus, in a squad of men investigated by Benedict the normal demand of the men for food ranged from 3,200 to 3,600 net Calories. After a loss of 12 per cent. in the body weight had been reached they were able to maintain this weight and to carry out their normal work with a diet of 2,300 Calories—*i.e.*, a diminution of one-third in their previous food requirements.

'This seems to have been the condition of the greater part of the urban inhabitants of Germany during the war, these having received a daily allowance of food of not more than 2,000 Calories. They lost weight, but they were stated to be able to carry out their ordinary work under the stress of circumstances in which they were placed. The heavy workers in Germany had to receive a supplementary ration, since the diminution of weight does not diminish the amount of chemical change necessary for the performance of mechanical work. This state of economical nutrition seems to be without danger to health even when extended over some months. When extended over years, as in Germany, the general effect appears to be a diminution in the resistance to tubercular infection, the incidence of tuberculosis and the deaths from this disorder having largely increased in all parts of Germany.

'On children the effect of the diminished diet has been to restrict growth, but not to stop it. Experiments on animals, as well as German observations, tend to show that a return to normal conditions will probably be followed by an increased rate of growth, which will be sufficient to make up for that lost during the past years. The economy in the case of children is probably effected by diminution of their spontaneous muscular activity in play. It seems that the community could exist, and could carry out a fair amount of work with a diminution of food supplies to two-thirds of their present amounts. In this case, however, it would be necessary to supply a strong incentive to the performance of work. . . .¹

The effects of insufficient feeding in diminishing resistance to cold have already been alluded to (p. 49), and were strikingly seen in some episodes of the American Civil War, a detailed account of which has been provided by Flint.² Its effects in producing liability to disease were well illustrated in the outbreaks of relapsing fever and typhus which followed the potato famine in Ireland³ in the early part of this century, and similar results have repeatedly been witnessed in India and elsewhere, fever and plague dogging the footsteps of famine. It has also been pointed out that exposure to infection is specially apt to be dangerous on an empty stomach, as, for example, before breakfast, a fact which it is important for doctors and nurses to bear in mind.

The tubercle bacillus seems to find a peculiarly favourable soil in ill-nourished persons. The association between bad feeding and such diseases as phthisis and scrofula is well established, while an improvement in nutrition is not infrequently followed by their cure. This may be the reason why diabetics, who live in a chronic state of partial starvation, are so liable to tuberculosis, and tall men, who, for reasons already discussed, have less food to spare than their fellows of less stature, are believed to be more subject to consumption than the latter are.

Epidemic ophthalmia is another disease which seems prone to select the underfed as its victims, and it might be well when it breaks out, as it is so apt to do, among the children of Poor Law

¹ Food (War) Committee Report, *loc. cit.*

² 'Physiology of Man,' New York, 1867, p. 35.

³ See Life of William Stokes in 'Masters of Medicine' Series, p. 110 *et seq.*

schools and other public institutions, to look more to the possibility of defective diet and less to overcrowding as the cause.

It is considerations such as these which entitle one to regard the repeal of the Corn Laws, which has done so much to cheapen food in this country, as a hygienic quite as much as an economic measure, and the diminished death-rate which has been so conspicuous in the latter part of the last century may have had more to do with it than one commonly thinks.¹

There is reason to fear, however, that large sections of the community in this country are still habitually underfed. Observations on the diet of labourers in Edinburgh² showed that it contained on an average only 107·7 grammes of protein, as against Atwater's standard of 125 grammes, and an energy value of only 3,228 Calories, as opposed to the 3,500 which he believed to be necessary for a labouring man. Mr. Seeböhm Rowntree's inquiries into the diet of a corresponding class in York³ yielded similar results, the energy value being 17 per cent., and the protein average no less than 29 per cent. below standard requirements. There is urgent need for more extended studies on similar lines to these.⁴ Meanwhile, it may be pointed out that the defects above indicated are due not so much to poverty as to ignorance; not to buying too little food, but to buying the wrong articles. The Edinburgh investigators were of opinion that in order to improve the dietary of the labouring classes the following principles should be instilled into them:

1. That a diet of tea and bread or of tea, bread, and butter (the lazy diet) is faulty.

2. That the faults of the tea and bread diet can be corrected by the free use of meat, eggs, or other animal food, but that this mode of correction is expensive.

3. That the faults can also be corrected by the free use of oatmeal with milk, or of peas or beans, without extra cost.

The bad effects of underfeeding fall most heavily upon the young, for the greater the demand on the part of the body for food, the more

¹ For particulars of the enormous all-round improvement which has taken place in the abundance and variety of the diet of agricultural labourers in this country in the last half-century, see a paper on 'Agricultural Wages in England and Wales during the Last Fifty Years,' by A. Wilson Fox (*Journ. Roy. Statist. Soc.*, 1903, lxvi, 273). Similar information will be found in the volume entitled 'Labour and Protection,' edited by H. W. Massingham (London: T. Fisher Unwin, 1903). For statistics on the fall in the price of food in recent years, see Memoranda, etc., on British and Foreign Trade and Industrial Conditions (London: Eyre and Spottiswoode, 1903).

² *Loc. cit.*

³ 'Poverty: A Study of Town Life' (London: Macmillan and Co., Ltd., 1903, new edition, p. 234).

⁴ For earlier studies of diets in this country, in which, however, the carbon and nitrogen standard was employed, see 'On the Dietaries of Scotch Agricultural Labourers' and 'On the Economic Condition of the English Agricultural Labourer,' by Robert Hutchison, F.R.S.E. (*Trans. of the Highland and Agricultural Society of Scotland*, 1867 and 1871). Also Oliver, 'The Diet of Toil,' a paper read at the Congress of Hygiene and Demography, Buda-Pesth, September, 1894. For references to some more recent dietary studies in this country see p. 34.

severely is any deficiency felt.¹ The recognition of this fact is as old as Hippocrates, who devoted a special aphorism to the statement of it. 'Old men,' it runs, 'bear want of food best; then those that are adults; youths bear it least, most especially children, and of them the most lively are the least capable of enduring it.'

The remote results of underfeeding are not less injurious than its more immediate effects. Amongst such results, impairment of digestive power is very conspicuous.² The danger of stuffing a starving man is notorious, but even in chronic underfeeding the same weakening of the digestive organs is observed. It is often seen in dyspeptics. The more their nutrition fails through not eating, the less they are able to digest, and the first step in curing their stomach troubles must often be in the direction of compelling them to eat more.

Another of these remote dangers is in the influence of imperfect feeding upon the mind. I refer not merely to a lowering of mental power, but to that feeling of dissatisfaction, discomfort, and depression, culminating sometimes in madness and hallucinations, which imperfect nutrition of the brain is apt to produce.

'A hungry man is an angry man,' and the proverbial good nature of the Englishman may, perhaps, be associated with the fact that, as a rule, he is full fed. The dangers here alluded to have been eloquently described by Dr. King Chambers³ in the following passage, with which I may close this chapter:

'Deficient diet, like all morbid conditions, both corporeal and mental, is a vitiating and degenerating influence. Famine is naturally the mother of crimes and vices, not only of such sort as will satiate the gnawing desire for food, but of general violence and lawlessness, ill-temper, avarice, lust, and cruelty.

'The love of purposeless destruction exhibited by the Parisian Communists in our own day may be fairly credited to deficient food. No well-fed people could have wrecked the Vendôme Column or burnt the Town Hall and Tuileries, of which they were so proud. They were like hungry children smashing their dolls. And Thucydides, Boccaccio, and Defoe are all agreed as to the hideous wickedness exhibited at Athens, Florence, and London during their famine-fevers. The exceptional instances are those where individuals or nations have conquered by courage and self-restraint their natural selfishness, and have made the interests of others paramount to their own. Am I blinded by love of my country, or may I justly quote the history of the Lancashire cotton-famine as a case in point?'

¹ See 'Feeding in Relation to the Health of the Young,' by James Niven, M.A., M.B. (London and Manchester: Sherratt and Hughes, 1904).

² It is an interesting question whether the effect of town life in impairing digestive power may not be partly responsible for the habitual underfeeding so often found in the industrial section of urban communities. It is possible, in other words, that the town worker may in many cases be incapable of digesting enough food to keep him in an ideal state of physical efficiency.

³ 'Manual of Diet in Health and Disease,' second edition, 1876, p. 223.

CHAPTER IV

ANIMAL FOODS

IN previous chapters we have dealt with foods in general. We have studied the nature and uses of their nutritive constituents, the standards by which one judges of their relative values, the amount of food required to maintain the body in a state of health, and the directions in which this amount must be modified in accordance with various influences and conditions. We have also glanced at the general results of over and under feeding. In this and a number of succeeding chapters we shall undertake the study of individual foods in detail, and in dealing with each shall consider (1) its physical structure and chemical composition ; (2) its behaviour in the stomach and intestine ; (3) its nutritive value in the body ; (4) its true economic worth.

We may begin our studies with foods derived from the animal kingdom ; but it will be well to defer the consideration of the general characters of the group as a whole until we are in a position to contrast them with the vegetable foods.

A convenient classification of the animal foods is as follows :

1. Meat, including the several varieties of butcher's meat, poultry, game, and ' offal.'
2. Gelatin and the foods prepared from it (jellies).
3. Soups, beef-extracts and beef-powders, beef-tea and beef-juices.
4. Fish and its allies.
5. Milk and its derivatives, including cream, butter, and cheese.
6. Eggs.

I. MEAT.

We may look first at the physical structure or architecture of meat (Fig. 4).

If one examines a piece of boiled meat, it will be found that it can easily be torn into a number of long, stringy fibres. On micro-

scopic examination, these would be found to be made up in their turn of bundles of microscopic tubes, known to the histologist as muscle fibres. The fibres vary in length in different kinds of meat.

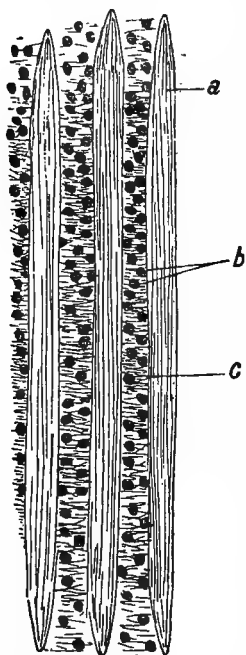


FIG. 4.—DIAGRAMMATIC REPRESENTATION OF THE STRUCTURE OF MEAT.

a, Muscle fibres; *b*, Fat cells; *c*, Connective tissues.

Sometimes they are short, as in the breast of a chicken; at other times they are much longer, as in the leg of a crab; and the shorter they are, the more tender and easily digested the meat is. Meat should be cut or carved at right angles to the long axis of the fibres. It is then more easily chewed, and, the contents of the tubes being exposed, the flavour is increased, while the action of the digestive juices is facilitated.

The walls of the tubes consist of an albuminoid substance (elastin), while the connective tissue which holds together the fibres is chiefly composed of a material called 'collagen,' which yields gelatin on boiling. The older an animal is, and the more work its muscles have had to perform, the denser is the connective tissue and the thicker the walls of the tubes. The latter fact was long ago pointed out by Dr. Kitchiner in his 'Cook's Oracle.' 'That exercise produces strength and firmness of fibre,' he says, 'is excellently well exemplified in the woodcock and partridge. The former flies most, the latter walks; the wing of the woodcock is

always very tough, of the partridge very tender; hence the old doggerel distich:

If the Partridge had but the Woodcock's thigh,
He'd be the best bird that e'er doth fly.'

Embedded in the connective tissue between the fibres is a variable amount of fat. Sometimes it is almost entirely absent—*e.g.*, in most forms of game and in the breast of the chicken; at other times the amount of fat so placed is quite abundant. This is the case in pork, in highly-fattened beef or mutton, and in swimming birds, such as the duck and goose, which require a large store of fat, both to lighten the body and as a source of heat. A large amount of fat tends to

diminish the digestibility of meat, apparently by forming a sort of waterproof coating around the fibres and hindering their solution by the gastric juice, and it is notorious that pork, duck, and goose are rather indigestible forms of flesh.

The contents of the microscopic tubes or muscle fibres consist of water holding in solution proteins, salts, and the substances known as 'extractives,' the whole constituting muscle-juice. The younger the animal, the more water does its flesh contain, and the lower is its nutritive value. This may be the explanation of the German saying, 'Calf-meat is half-meat.'

The chief proteins which the juice contains are myosin, muscle albumin, and hæmoglobin, the first being the most important. Myosin has the property of clotting after death, the hardening of the muscle which results being known, it will be remembered, as *rigor mortis*, or death-stiffening. Meat in that condition is tough, and accordingly, if tenderness is desired, the meat should be eaten either immediately after the animal is killed, and before *rigor mortis* has had time to set in, or else it should be allowed to hang till the *rigor* has passed off. The disappearance of *rigor* is due to a resolution of the myosin by the development of acids,¹ and to a partial digestion of it by the traces of pepsin which muscle contains. The process must be regarded as an early stage of putrefaction, and, as is well known, if the meat be allowed to hang for some time longer it becomes 'high.'

The acids which develop in meat on hanging aid the gelatinization of the connective tissue which occurs on boiling, and also improve its flavour by removing the rather insipid flatness of taste which characterizes very fresh meat. In the flesh of animals which have undergone great muscular exertion immediately before being killed there is a considerable quantity of acid present even at the time of death. Hence the flesh of hunted animals is of a superior flavour, and in less humane ages and countries attempts have been made to develop this flavour in domestic animals artificially by urging them to frantic exertions before slaughter. Another way of producing these effects by artificial means is by soaking the meat in vinegar and water for a short time. This is found to improve the flavour of fresh meat, as well as its tenderness. It is partly for the same reason that the use of vinegar favours the digestibility of the hard muscles of the crab and lobster.

The amount of hæmoglobin, or red colouring matter, in the juice varies greatly in different kinds of meat, and is usually less in

¹ Sarcolactic acid and acid phosphates.

amount in that obtained from young animals. It is of importance as containing iron. Hæmoglobin is also found in the small blood-vessels which form a network around the fibres of meat. In animals which have been bled to death it is much diminished in amount or altogether removed; hence the pallor of veal.

The chief mineral substances found in the juice of meat are phosphoric acid and potash. Meat must be regarded as one of the principal sources of these valuable building materials in the diet, and if they are insufficiently supplied, the muscles are flabby and badly developed.

Last, but not least, of the substances contained in solution in the juice of meat are the **extractives**. These are so called because they can be 'extracted' from meat by means of boiling water, and are familiar to everyone as the dark brown, sticky material which constitutes the chief part of Liebig's Extract. We shall have much to learn about these extractives later on, but it may be stated here that their exact chemical nature is to a large extent unknown, that they have no direct nutritive value, but are of importance as being the chief cause of the characteristic taste of meat, and that, therefore, when they are removed, as they are, for example, on prolonged boiling, the meat becomes flavourless and insipid. Further, it would appear that the **characteristic flavours of the different kinds of meat** are due to minute differences in the amount and kind of the extractives present. The age of the animal and the way in which it is fed are of great importance in this connection. The flesh of full-grown animals is richer in extractives and has a fuller flavour than the flesh of those which are immature, which explains why we eat lamb with mint sauce and add spices to veal. The influence of feeding, on the other hand, is well illustrated by all forms of game. The flesh of wild rabbits, which eat aromatic herbs, especially thyme, has a much finer flavour than that of rabbits which are fed by hand, and a slice of wild duck is generally admitted to be a more tasty morsel than a piece of the bird reared in a farmyard. Everyone knows, too, how 'fishy' sea-birds taste, how superior hill mutton is to its turnip-fed substitute, and how in grouse or capercaillie one can detect, as it were, an echo of the aroma of the heather-tops or pinewoods amongst which these birds live.

The **chemical composition of meat** varies considerably, depending as it does on the particular 'cut' examined, on the breed of the animal, and on the degree to which it has been fattened. It must be noted, also, that by no means the whole of ordinary butcher's meat consists of edible matter, a large part being made up of bone, gristle, tendon, and

other inedible portions. In an average piece of meat these waste matters may be reckoned at 15 per cent. of the whole, and the proportions of the constituents in the edible part are about as follows (König) :

Water	..	..	75 to 77 per cent.
Muscle fibres	..	..	13 to 18 "
Connective tissue	..	..	2 to 5 "
Fat	..	..	$\frac{1}{2}$ to 3 "
Ash	..	..	0.8 to 1.8 "
Extractives	..	..	$\frac{1}{2}$ "

Other analyses represent the proportions of the chemical substances present thus :

100 Parts of Lean Beef without Visible Fat (Bischoff and Voit).				100 Parts of Dry Substance (Rubner).			
Protein	..	..	18.36	Syntonin, myosin, and gelatin	70.1		
Gelatin	..	..	1.64	Hæmoglobin and serum albumin	8.57		
Fat	..	..	0.90	Muscle albumin	3.13		
Extractives	..	..	1.90	Extractives	12.68		
Ash	..	..	1.30	Ash	5.50		
Water	..	..	75.90				

The effects of fattening are shown in the following table, in which the composition of lean, medium, and very fat beef are stated in round numbers :

	Water.	Nitrogenous Matter. ¹	Fat.	Ash.
Lean..	76.5	21	1.5	1
Medium	73	20.5	5.5	1
Very fat	53	17	29	1

The chief points to note in this table are : (1) The large amount of water which meat contains. About three-quarters of its total weight is made up of water, or, stated otherwise, 1 pound of meat contains $\frac{3}{4}$ pound water and $\frac{1}{4}$ pound of nutriment. It has been already pointed out that the flesh of young animals is relatively richest in water. (2) The relation between water and fat. The more there is of the latter present, the less there is of the former ; in other words, when fat is deposited in a muscle, it replaces water, and not protein, and so the gain in nutritive value is an absolute one, and is not attained at the expense of a loss of nitrogenous constituents. The above analyses refer especially to beef ; the composition of the other commoner sorts of meat and some varieties of game may be graphically represented as follows :²

¹ 'Nitrogenous matter' is the figure obtained by multiplying the amount of nitrogen in 100 parts by 6.25 ; *i.e.*, it is assumed that it is all protein. In reality 15 per cent. of the total nitrogen is present in the form of extractives, the amount of which can be calculated by multiplying their nitrogen by 3.12 (Stutzer's factor).

² Most of the analyses from which the diagram is constructed are by König and Stutzer. The analysis of lamb is from Atwater, that of bacon from Church.

BEEF (medium fat).	76.5		20	15.3
MUTTON (lean).	75		18	57.3
MUTTON (medium fat).	65.2	14.5	19.5	08
MUTTON (very fat).	46	10.2	43.2	06
VEAL.	71		17	11
LAMB (medium fat).	63.9	18.5	16.5	11
PORK (medium fat).	60.9	12.3	26.2	06
PORK (very fat).	44.4	9.7	45.5	04
BACON.	22.3	8.1	65.2	14.4
HARE.	74		22.3	11.1
RABBIT (fat).	66.8	21.4	9.7	11
VENISON.	75.7		19.7	19.1
FOWL.	70.0		23.3	3.1
WILD DUCK.	70.8		22	3
GOOSE.	38.0	15.9	45.5	04
PIGEON.	75.1		22.1	10.0

WATER. 

PROTEIN &
GELATINE. 

FAT. 

ASH. 

The following table shows the composition of the commoner poultry :¹

COMPOSITION OF POULTRY.

	Water.	Protein.	Fat.	Ash.
Fowl, young :				
Dark meat.. .. .	70.1	20.8	8.2	1.2
Light meat	70.3	21.9	7.4	1.1
Giblets	71.0	19.8	6.4	1.3
Turkey :				
Dark meat.. .. .	57.0	21.4	20.6	1.1
Light meat	63.9	25.7	9.4	1.3
Giblets	56.7	17.7	23.5	1.2
Duck :				
Meat, not including breast or giblets..	55.5	17.4	26.1	1.0
Breast	73.9	22.3	2.3	1.3
Giblets	73.2	17.9	5.0	1.8
Goose :				
Meat, not including giblets	51.8	16.2	31.5	1.0
Giblets	70.0	20.1	8.2	1.7

¹ United States Department of Agriculture, Farmers' Bull. No. 234.

It must be clearly realized that these results are merely approximate, and may vary considerably in different cases. Thus, in very young calves the amount of water in the flesh may be 80 instead of only 71 per cent. The relative proportions of gelatin and protein also fluctuate considerably. The proportion of the former is highest in the flesh of young animals—hence the value of veal as a basis for soups—and is lowest in game. As regards the amount of the extractives, but few data are available, but the latest investigations tend to show that the red meats are richest in these constituents.¹

Hitherto we have been dealing with the structure and composition of meats in their raw state, and we must now direct our attention to the changes which are effected in them by **cooking**. The full consideration of this subject may be conveniently deferred to another chapter (Chapter XXII.), but at present one may note that the general effect of cooking on the *structure* of meat is (1) to loosen the fibres by converting the connective tissue which holds them together into gelatin, and (2) to remove some of the fat, the exact proportion lost depending on its melting-point, and being higher in cake-fed than in pasture-reared animals.

The chief effect of cooking on the chemical composition of meat is to diminish the amount of water which it contains. This results, curiously enough, even when the meat is boiled. This is important, for it means a very considerable increase in the nutritive value of cooked, as compared with raw, meat, a result which is the very reverse of that which follows the cooking of vegetables (p. 405). In consequence of this **loss of water**, an ordinary plateful of cooked meat, weighing 4 ounces, may be regarded as equivalent to 5 ounces of raw meat. Another effect of cooking on the chemical composition of meat is the removal of part of the extractives. This is most marked when boiling is the method employed, but it also occurs to a considerable extent even in roasting. Some of the salts are also dissolved out by boiling, and reference has already been made to the fact that cooking removes some fat as well. These general effects of cooking are illustrated in the following analyses by König of a piece of meat before and after cooking:²

¹ Adler, *Berlin Klin. Woch.*, 1908, xlv. 393.

² For further information on this subject, see 'Experiments on Losses in Cooking Meat,' by H. S. Grindley and Timothy Mojonner, United States Department of Agriculture, Office of Experiment Stations, Bull. No. 141, 1904.

		Water.	Nitrogenous Matter.	Fat.	Extractives.	Mineral Matter.
Beef: raw	..	70.88	22.51	4.52	0.86	1.23
boiled	..	56.82	34.13	7.50	0.40	1.15
roasted	..	55.39	34.23	8.21	0.72	1.45
Veal cutlets:						
raw..	..	71.55	20.24	6.38	0.68	1.15
roasted	..	57.59	29.00	11.95	0.03	1.43

The following results were got by Tankard.¹ They represent the composition of various kinds of meat cut from the cold roast joint, and wholly edible. They include such a proportion of fat as would be commonly helped and eaten with the lean, but are exclusive of skin, gravy, and dripping:

	Mutton.	Lamb.	Beef.	Veal.	Pork.	Duck.	Fowl.
Water (dried at 100° C.)	39.76	59.89	45.63	51.88	44.90	64.13	67.40
Fat (ether ext.) ..	26.80	11.95	24.21	11.39	19.67	6.06	6.68
Protein (N x 6.3) ..	29.04	24.69	26.50	32.19	32.63	27.12	24.26
Ash	1.93	1.63	1.21	1.57	1.86	2.04	1.37
	97.53	98.16	97.55	97.03	99.06	99.35	99.71

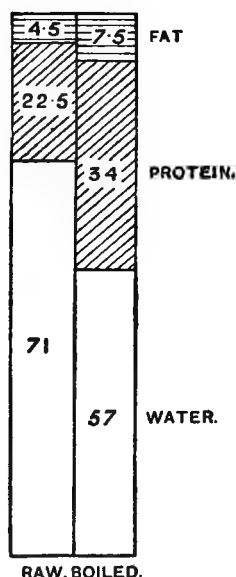


FIG. 6. — COMPARATIVE COMPOSITION OF RAW AND BOILED BEEF.

Taking König's figures, the composition of raw and boiled beef may be graphically compared as in Fig. 6.

2. DIGESTIBILITY AND ABSORPTION OF MEAT.

All solid foods are digested in the stomach in a *physical* sense; that is to say, they are reduced to a fluid or pulp, in which condition alone they are able to pass on into the intestine. But meat is a food the main share in the *chemical* digestion of which also falls to the lot of the stomach; that is to say, its chief nutritive constituent (protein) is there got into a form fit for absorption. Now, it may be laid down as a rule that the greater the extent to which the chemical digestion of a food goes on in the stomach, the easier does its mechanical digestion prove. Hence, although meat makes considerable demands on the gastric juice, it does not throw any great strain on the mechanical resources of

¹ Allen's 'Commercial Organic Analysis,' iv. 269, second edition, 1898.

the stomach, and for that reason it must be regarded as among the more easily digested of the solid foods.

The first change which takes place during the digestion of meat is that the fibres swell up and become softened; their colour then changes to a grayish-yellow; they fall apart, and the mass becomes pulpy. Last of all, the individual fibres split up either into longitudinal threads or transversely into discs. It will be evident that the ease with which these changes can occur must depend on many conditions. The harder and denser the connective tissue which holds together the fibres, the less readily will they separate, and the greater the amount of fat between the fibres, the less readily can the gastric juice act upon the latter, hence the indigestibility of tough and fat meats. The longer and thicker the individual fibres, the more slowly are they split up; hence the improvement in the digestibility of tough meat which results from breaking up the fibres by pounding the meat across its cut ends. The influence of cooking also is of great importance. It has been found by experiments on man¹ that 3½ ounces (a small helping) of beef disappears completely from the stomach in the following times, depending on the method by which it has been cooked:

Raw	2 hours.
Half boiled	2½ "
Wholly boiled	3 "
Half roasted	3 "
Wholly roasted	4 "

Artificial experiments outside the body corroborate these results. Popoff² found that the proportions digested in a given time were as follows:

Raw	100 parts.
Boiled	83·4 "
Smoked	71 "
Boiled and smoked	60·6 "

Stutzer³ found that, of 100 parts, there is dissolved in half an hour:

	Raw.	Boiled.
By weakly acid juice	89·2 per cent.	38·7 per cent.
By normal juice	96·9 "	79·3 "

Similar experiments by Chittenden and Cummins⁴ confirm these conclusions, and the only experiments with which I am acquainted which resulted differently were some by Uffelmann⁵ on a boy with a gastric fistula, in whom it was found that raw meat was digested

¹ Jessen, *Zeit. für Biologie*, 1883, xix. 129.

² Popoff, *Zeit. für Physiol. Chemie*, 1890, xiv. 524.

³ Weyl's 'Handbuch der Hygiene,' Bd. iii., p. 216.

⁴ *American Chemical Journal*, 1884-85, vi. 318.

⁵ *Deut. Archiv. für Klin. Med.*, 1877. xx. 535.

rather more slowly than roast, although the fibres of the latter fell apart more rapidly.

On the whole, one may conclude that most forms of cooking tend to lessen the digestibility of meat in the stomach, a conclusion which applies, almost without exception, to *all* forms of animal food, but is quite the reverse of true as regards vegetable foods (see Chapter X.).

In accordance with these experimental results one finds that raw, or at all events much underdone, meat is a form of food which patients with very weak stomachs can digest more easily than most other forms of nourishment. The best method of preparing such meat is by scraping a piece of tender juicy steak with a blunt instrument in a direction parallel to the course of the fibres. This separates out the fibres from the enclosing connective tissue, and leaves the latter behind. The fibres form a pulp which can be seasoned with celery, salt, and a little pepper, and served either as a sandwich or stirred into broth. In what is known as the **Salisbury cure** another method of administration is adopted. The meat is chopped very thoroughly, all visible connective tissue and gristle being removed, and it is then made into little cakes $\frac{1}{2}$ to 1 inch in thickness, and of 3 or 4 inches diameter. These are placed in a clean frying-pan, strongly heated, but without either water or grease. When one surface of the cakes is seared they are turned over and the other heated similarly. They are then covered and set on the side of the fire till the red colour of the meat has been changed to a drab. They are finally seasoned with a little fresh butter and salt, and are ready to be served.

As regards the **relative digestibility of the different kinds of meat**, there are but few exact data available. There is a general impression that **mutton** is more easily digested than beef, which some have attributed to the finer fibres and looser connective tissue of the former. Jessen, however, found that $3\frac{1}{2}$ ounces of raw mutton were digested in precisely the same time as an equal weight of beef; while the experiments of Chittenden and Cummins showed that the digestibility of mutton, outside the body at least, was *inferior* to that of beef (92 as compared to 100). They admit, however, that the results varied greatly in different samples owing to age and other conditions. There can be no doubt that mutton fat, especially when hot, is particularly apt to prove irritating to the stomachs of some persons, and in them the eating of such articles as mutton pies or Irish stews is prone to be followed by an attack of acute gastric catarrh.

Veal is believed to be somewhat difficult of digestion, a belief

which is confirmed by experiment, for it required two and a half hours for its digestion, as compared with two hours for beef (Jessen). The difficulty of digesting veal is somewhat surprising, for the connective tissue, though abundant, is very easily changed into gelatin. It is believed by some that the explanation is to be found in the ease with which the fibres of veal elude the teeth on mastication; the rather insipid taste of veal may also be a contributive cause, for such foods do not tend to excite a free flow of gastric juice.

The comparative indigestibility of **pork** is shown by the fact that $3\frac{1}{2}$ ounces of it required three hours for their complete digestion, as compared with two hours for beef. The difficulty here is fully accounted for by the large accumulation of fat between the fibres. On the other hand, the fat of **bacon** seems to be in a granular form, which is not difficult to digest, and it can often be eaten with impunity by persons to whom other forms of fat are intolerable. For this reason bacon is an invaluable aid in feeding delicate children and diabetic or phthisical patients in whose diet the free use of fat is indicated.

The breast of **chickens and game** is amongst the most digestible forms of meat, but the leg muscles are often very tough. Very fat poultry should be avoided by the dyspeptic, as the fat of such birds is particularly apt to become rancid.

Lastly, it must be pointed out, in connection with the relative digestibility of different sorts of meat, that idiosyncrasy plays a very large part in the process. There are persons, for instance, whom mutton invariably makes ill, while they can eat beef with impunity, and others who can take mutton, but cannot touch beef. No explanation of such cases can be given.

The **absorption of meat** has already been referred to (Plate II.). It was shown that only about 5 per cent. of the organic matter in meat fails to enter the blood, and that as the result of this meat is a food which leaves a very small residue in the intestine. This gives it a special value in some cases of intestinal disease.

3. NUTRITIVE VALUE AND ECONOMY OF MEAT.

The principal nutritive constituent of meat is protein, and it is as a compact and easily digested source of this that meat is chiefly of value. Meat is thus one of the best sources of building material for

the body. We have also seen that protein is characterized by the rapidity with which it can be broken down by the cells with the liberation of heat, or, in other words, that it is a 'quick fuel.' It is to this fact, probably, that meat owes the 'heating' qualities commonly ascribed to it, and for a similar reason its use should be restricted in hot weather. The use which is made of meat in training has been justified on the same grounds (p. 38). Another characteristic of protein is that it seems to exert a stimulating effect on the cells and on the body generally, and the feeling of well-being which follows a meat meal may be put down to this cause. In savages who are unaccustomed to meat the free consumption of it is said sometimes to produce a nervous excitement amounting almost to intoxication. For this reason, too, the presence of much meat in the diet seems to act as an exciter of the animal passions, and an eminent authority¹ has advised that in the treatment of cases in which such propensities require to be kept in check one should 'avoid flesh, as the incarnation of rampant, uncontrollable force.'

Meat is one of the few articles of diet on which life can be supported alone for an almost indefinite time. It cannot, however, be regarded as constituting in itself anything like a perfect food. It is relatively much too rich in protein and too poor in other nutritive constituents. It would require about $4\frac{1}{2}$ pounds of it a day to supply the energy required, and such a quantity would be apt to damage the digestion, besides overloading the blood with nitrogenous waste products.

The almost exclusive use of lean meat is the basis of the 'Salisbury cure,'² to which reference has already been made, and it has also been recommended as a means of treating some diseases of the skin—*e.g.*, psoriasis³—which have resisted the ordinary remedies. The use of meat in such diseases as diabetes, gout, and obesity, will be dealt with in another chapter.

The relative nutritive value of different sorts of meat depends chiefly on the amount of fat they contain. Fat, as we have seen, replaces part of the water, and not the protein, of the leaner meats, and thus the fat meats are better sources of fuel than the latter, while not inferior to them in building material. Apart from this, the nature of the extractives present may perhaps have some influence on general metabolism. Dr. Smith⁴ tells us that Kean, the famous

¹ Clouston, 'Insanity,' p. 520. See also Mr. Eustace H. Miles's 'Better Food for Boys' (London: George Bell and Sons, 1901).

² 'The Relation of Alimentation and Disease'; Salisbury, New York, 1895.

³ Parkes, *Lancet*, 1874, i., p. 722.

⁴ *Food*, p. 52.

actor, used to adapt the kind of meat he ate to the part he had to play, choosing pork for tyrants, beef for murderers, and mutton for lovers. This may seem far-fetched, but it may indicate that there are subtle differences in the different kinds of meat which chemistry does not enable us to detect, but which are yet not without influence upon the body.

From an economic point of view meat is a dear food. This is clearly shown in Plate III., and holds good whether one regards meat merely as a yielder of energy or as a source of building material.

The costliness of it, however, can be considerably diminished by selecting the cheaper 'cuts,' which are equal in nutritive value to the dearer kinds, though inferior in tenderness and flavour. The question of waste from bone, etc., must also be considered. Thus, in the case of mutton and pork, the leg contains relatively less bone than the shoulder, and in beef there is a much larger proportion of bone in the shin than in the round, and of these the least bony parts will be the most economical from a nutritive point of view. Much, too, can be done to diminish the cost by the use of the cheap frozen meats which are now imported. These are equal in nutritive value to fresh meat, and are only slightly inferior to the latter in keeping qualities. They are not drier than ordinary meats, as is often stated, for chemical analysis shows that the proportion of water is only 10 per cent. less than that of fresh meat, while their digestibility is precisely the same.¹ From an economic point of view, also, it must be regretted that there exists a prejudice against the use of horseflesh as a substitute for ordinary meat. It is well flavoured—indeed, a Châteaubriand steak is said by connoisseurs to be best when made of horseflesh—and any toughness can be overcome by suitable cooking. In Paris the use of horseflesh for human food is increasing every year, and one can only hope the poorer classes in this country may ultimately take to it too. Indeed, it is stated to be already largely used in the manufacture of smoked meats.

There is also a prejudice against the use as human food of the flesh of animals which have died of disease. This, again, can hardly be justified on grounds either of science or experience. The shepherds of Scotland have long used 'braxy' mutton—i.e., the flesh of sheep which have died of various diseases—and I am not aware that it has ever been known to produce any harmful

¹ Gautier, 'Frozen Meat as an Article of Diet' (abstract in *Edinburgh Medical Journal*, 1897, N.S., ii. 200).

results. A French observer¹ has put the matter to the test of experiment. He took the flesh of animals which had died of various diseases (including that of the mad dog!), cooked it in various ways, and gave it to people who were ignorant both of its nature and source. No bad effects followed its consumption. He concludes, fairly enough, that the use of diseased meat is harmless provided it be properly cooked, and that the overstrict inspection of slaughter-houses may do more harm by rendering meat dear, and therefore inaccessible to the poor, than it does good by preventing disease.

It should be remembered that all small animals, such as rabbits, are necessarily expensive forms of meat both on account of their active metabolism, which implies that the greater part of the food they eat is lost in the form of heat, and also because of the relatively large bulk of their viscera. It is therefore impossible to hope that they can ever be a suitable form of animal food for the poorer classes.

There remain to be dealt with some parts of animals, other than the flesh, which are sometimes used for foods, and which are usually classed together under the somewhat unsavoury title of *offal*. These comprise such articles as the kidneys, liver, sweetbreads, blood, heart, lungs, and other internal organs, and together make up about one-third of the total weight of the carcase.

The general composition of these articles is shown in the following table :

COMPOSITION OF OFFAL.

			Water.	Nitrogenous Matter. ²	Fat.	Carbo- hydrates.	Ash.
Kidney (ox)	..	..	76·7	16·9	4·8	0·4	1·2
" (sheep)	..	..	78·7	16·8	3·2	—	1·3
Liver (ox)	..	..	71·2	20·7	4·5	1·5	1·6
" (sheep)	..	..	61·2	23·1	9·0	5·0	1·7
Heart (ox)	..	..	62·6	16·0	20·4	—	1·0
" (sheep)	..	..	69·5	17·0	12·6	—	0·9
Lung (ox)	..	..	79·7	16·1	3·2	—	1·0
" (sheep)	..	..	75·9	20·2	2·8	—	1·2
Sweetbreads	..	..	70·9	16·8	12·1	—	1·6
Blood	..	..	80·8	18·1	0·2	—	0·85
Tripe	..	..	74·6	16·4	8·5	—	0·5
Tongue (ox) fresh	..	..	63·8	17·1	18·1	—	1·0
" smoked and salted	..	..	35·7	24·3	31·6	—	8·5
Brain	..	..	80·6	8·8	9·3	—	1·1

¹ Decroix, 'Recherches Expérimentales sur la Viande de Cheval et sur les Viandes Insalubres'; Paris, 1885.

² N x 6·25.

It will be observed that, from the chemical point of view, they are substances of considerable nutritive value, and as their price is also for the most part low, as compared with that of ordinary meat, they must be regarded as important sources of protein in the diet.

The **liver and kidneys** resemble one another in being compact, solid organs, containing but little connective tissue. This physical property renders them somewhat difficult of digestion, unless they have either been minced before cooking (as the liver is, for instance, in making a haggis), or are rather carefully chewed. Chemically, both consist chiefly of protein along with a small amount of fat. The protein which they contain is quite different from that of ordinary meat, consisting as it does to a large extent of nucleoprotein, which yields nuclein on digestion. Now, nuclein is an important source of uric acid, and for that reason it may be well for gouty persons to avoid the dietetic use of the articles under consideration.

The **heart** resembles ordinary meat very closely as far as chemical composition is concerned, but differs from it in being of a denser structure, and therefore less digestible. For healthy persons, however, it is an excellent and economical food, and might with advantage be made larger use of than it is at present.

It seems natural to suppose that blood must be a very valuable food. 'The blood is the life,' and it would seem as if blood must represent in itself the essence of strength and energy. But it is not so; and the misconception proceeds from a neglect of the fact that blood is not *in itself* the food of the tissues, but is merely the vehicle by means of which nourishment is carried from the intestines to the places where it is wanted in the body. One might as well expect a spoon to be of nutritive value because it conveys food from the plate to the mouth. Two French experimenters¹ found that blood when administered to dogs, even in the liberal measure of 2 pounds daily, did not suffice to maintain the life of the animals for more than a month. This is due in part to the fact that blood is a dilute fluid, for, of every 100 parts of it, from 78 to 82 consist of water. Blood, in fact, from a chemical point of view, is not so much thicker than water after all. In the solids there is plenty of protein, but the other nutritive constituents of food—fat and carbohydrates—are only represented in quite inappreciable amount. In addition to this, the red colouring matter (hæmoglobin) which makes up the larger part of the protein is a substance which is very far from being

¹ Payen and Magendie.

completely absorbed.¹ There are, thus, no chemical considerations which can outweigh the natural repugnance which most persons feel to the eating of blood; and though it may be used without harm, if also without much benefit, in the form of black-puddings and such-like, there is no reason to advocate its habitual consumption, much less its employment in the feeding of the sick; and this is true also of the use of blood as a source of iron.²

The lungs, from the fact that the air which they contain enables them to float in water, are popularly spoken of as the 'lights.' They are sometimes eaten, but cannot be regarded as a really good form of food. Their chemical composition furnishes the reason. The lungs are largely composed of an elastic material belonging to the group of albuminoids, and only imperfectly capable of digestion, besides being useless as building matter in the body.

Under the term *sweetbread* butchers include at least two distinct organs. The 'throat sweetbread' is known to anatomists as the thymus gland; the 'stomach sweetbread' is the pancreas. The thymus of the calf is the one most frequently met with in the market. Both glands are cellular organs, held together by a loose and delicate connective tissue. From the nature of the latter they are easily dissolved in the stomach, and rank amongst the most digestible of animal foods, 9 ounces of sweetbread being completely disposed of by a healthy stomach in two and three-quarter hours, while a similar weight of beefsteak demands at least four and a half hours for its complete digestion.³ The cells of these organs are chiefly composed of nucleo-protein, and for that reason, as has already been pointed out in the case of the liver and kidney, sweetbreads may prove harmful in some cases of gout.

Tripe is the name applied to the stomach and intestines of the ox after being cleaned and boiled. It contains a large amount of connective tissue, readily changed into gelatin on boiling, and so rendering the fibres easily digested. It contains fat in considerable amount, but not diffused through the muscular part. I am not acquainted with any experiments on its rate of digestion in the stomach, but in the intestine it has been found to be as completely

¹ See Gherardini, *Rev. des Sciences Méd.*, 1892, xxxix. 88; and Kobert, *St. Petersburger Med. Wochenschrift*, 1891, p. 439. Halliburton has investigated (*Brit. Med. Journ.*, 1904, i. 823) the digestibility and absorption of hæmoglobin. He found that it is to some extent at least digested by the pancreatic juice, and experiments on rats showed that under its administration the number of red cells in the blood rises, whilst the amount of iron in the tissues is increased.

² See Starck, *Deut. Med. Woch.*, 1898, xxiv. 805.

³ Penzoldt, *Deut. Archiv für Klin. Med.*, 1893, li. 535.

absorbed as beef.¹ Unfortunately, the absence of extractives causes tripe to be rather deficient in flavour, but otherwise it must be regarded as a valuable and easily-digested food.

The brain of animals is only occasionally eaten as food. Brain consists largely of a fatty material containing cholesterol and lecithin, the latter being comparatively rich in phosphorus. In the stomach, owing to its soft consistency, brain is more rapidly digested than any other animal food, but, unfortunately, it is very imperfectly absorbed, 43 per cent. of it reappearing in the fæces (*vide infra*). In spite, therefore, of its easy digestion, it cannot be regarded as a valuable food for invalids, nor is it in any sense specially apt to 'make brains.' 'Some fancy,' says an ancient writer,² 'that Rabbits' Brains weaken the Memory, because this animal cannot for a moment after retain in mind the Foils laid for her and that she had just escaped; but this conjecture, being grounded upon a weak Foundation, I shall not stop here and go about to confute it.' The idea that brain can in any way contribute to the nourishment of brain is grounded on an equally 'weak foundation.'

The comparative absorption of some of the articles of which we have been speaking, as found by experiment, is as follows:

Voit³ states that

100 parts of dry liver yield 5 parts of dry fæces.					
"	"	lung	"	8	"
"	"	thymus	"	7	"
"	"	brain	"	43	"

Emil Bergeat⁴ found the loss of nitrogen in the dog to be:

In meat	..	..	..	2.1	per cent.
In thymus	..	..	..	3.2	"
In liver	..	..	..	3.3	"
In lung	..	..	..	4.2	"
In brain	..	..	..	13.9	"

The average composition of some potted meats is represented the following table (from König):

	Water.	Nitrogenous Matter.	N-free Extractives.	Fat.	Ash.	Salt.
Foie gras ..	46.04	14.59	2.67	33.59	3.11	0.22
Potted beef ..	32.81	17.17	3.36	44.63	2.03	
" ham ..	25.57	16.88	—	50.88	6.78	5.72
" tongue ..	41.52	18.46	0.46	32.85	6.71	5.98

¹ Solomin, *Arch. für Hygiene*, 1906, xxvii. 176.

² Lemery, 1745.

³ *Zeit. für Biologie*, 1889, xxv. 232.

⁴ *Ibid.*, 1888, xxiv. 120.

These substances require no special description.

Sausages are preparations of very uncertain composition. It has been remarked of them with some truth that they are like life; for you never know what is in them till you have been through them. In this country they are usually made of uncooked meat, but various vegetable substances, especially bread, are frequently added as well, and the vegetable matter is not infrequently disguised by the addition of colouring materials. Seasonings of various sorts also enter into their composition, and most of them contain a boron preservative. The following analyses by Allen¹ represent the composition of some typical kinds:

COMPOSITION OF SAUSAGES.

Variety.	Price per lb.	Water.	Fat.	Protein.	Gristle, etc.	Starch.	Ash.
Pork 'Cambridge'	9d.	54.99	21.04	12.28	0.67	1.05	3.52
pork	9d.	51.54	29.72	9.45	0.72	2.20	3.47
Mutton	1s.	55.58	30.51	1.89	3.11	3.90	2.50
German	8d.	46.54	17.87	16.38	1.13	15.00	4.47
Polony	10d.	45.57	32.66	17.26	0.54	2.30	2.80

As sources of protein, they are certainly not more economical than ordinary meat.

The use of bones as food will be dealt with in the next chapter.

¹ 'Commercial Organic Analysis,' second edition, vol. iv., p. 280.

CHAPTER V

JELLIES—FISH

THE chemical basis of jellies is gelatin. Gelatin is derived from collagen, which is the chief constituent of connective tissues, and is converted into gelatin by boiling. All forms of connective tissue can be made to yield gelatin by suitable treatment. Glue is a crude form of the substance obtained from hide-clippings, and ordinary commercial gelatin is simply a purified form derived from the same source. The connective tissues of young animals are especially rich in gelatin-yielding material. Veal, for example, contains 4 to 5 per cent. of connective tissue, and is therefore a favourite basis for the making of strong soups. Calves' feet (free from bone) yield 25 per cent. of gelatin on boiling and 11.3 per cent. of fat,¹ and have long been known as abundant yielders of a pure jelly. The purest form of all, however, is isinglass, a substance obtained from the swim-bladder of fish, especially of the sturgeon. Chemically it is not really richer than ordinary gelatin, as is shown in the following comparative analyses :²

				<i>Ordinary Gelatin.</i>	<i>Isinglass.</i>
Water	..	..	..	13.6	19.0
Albuminoid	..	..	..	84.2	77.4
Fat	..	..	..	0.1	1.6
Carbohydrate	..	..	..
Ash	..	..	..	2.1	2.0
Full value per pound	..	..	..	1,570 Calories.	1,510 Calories.

The chief physical peculiarity of gelatin is its capability of dissolving in boiling water, and setting into a jelly on cooling. It is remarkable how weak a solution is capable of doing this. Even when as little as 1 per cent. is present the solution sets. The ordinary strength of which jellies are made is 1 ounce of gelatin to the quart, which is equivalent to a 2 per cent. solution, and from this one can realize how little gelatin there really is in ordinary jellies.

¹ Uffelmann, 'Ueber Sparstoffe und deren Verwendung in der Kost der gesunden und Kranken,' *Wiener Klinik*, 1891, xvii., Heft 7.

² Atwater, 'Chemical Composition of American Food Materials,' Bulletin 28, United States Department of Agriculture.

I have found that 6 ounces (a large helping) of ordinary calf's-foot jelly contains $1\frac{2}{3}$ ounces of solid matter, of which less than $\frac{1}{2}$ ounce is gelatin, the remainder being chiefly sugar.

The digestion of gelatin in the stomach is a very easy process; indeed, in this respect it is hardly surpassed by any other food. Uffelmann found that, in a boy with a gastric fistula, complete peptonisation took place within an hour, but he does not state how much jelly was administered.

Gelatin has the advantage of fixing a good deal of acid in the process of digestion, and is thus of service in cases of hypersecretion of acid in the stomach. It seems also to belong to the 'peptogenic' substances—*i.e.*, those bodies which favour an abundant flow of gastric juice (see p. 417).

In estimating the nutritive value of gelatin,¹ it is important to emphasise again that gelatin is not capable of building tissues, and is in no sense a true substitute for proteins. This is due to the fact that some of the amino-bodies—*e.g.*, tryptophans—which are essential for the building up of human protein, are not contained in it. As a source of heat and energy, it is equal to protein or carbohydrate, 1 gramme yielding about 4.1 Calories.

It is as a sparer of protein, however, that gelatin is chiefly of importance in the food. It is the most powerful protein-sparer known, being able to save from destruction half its weight of protein, or twice as much as is spared by an equal quantity of carbohydrate; but in estimating its value in this direction as an ordinary food, it must be remembered that even those who live on a mainly animal diet do not consume more than one-tenth to one-eighth of their total nitrogen in the form of gelatin, and that probably not more than 25 to 30 grammes (about 1 ounce) of the latter substance can conveniently be taken in a day. This restricts its usefulness considerably, for even a quart of jelly would only be able to spare the protein in $2\frac{1}{2}$ ounces of meat; and assuming that 25 grammes of gelatin were contained in the diet, this would only effect a saving of 35 grammes of meat ($1\frac{1}{4}$ ounces) and 40 grammes of bread ($1\frac{1}{2}$ ounces). An ordinary slice of a 4-pound loaf weighs $2\frac{1}{2}$ ounces. One can realize from this that the usefulness of gelatin as a protein-sparer in fevers and diabetes is of limited range. As a pleasant addition to the diet of convalescence, however, jellies are of service, but their nutritive value depends mainly on the sugar which they contain, and

¹ See Murlin, *Amer. Journ. of Physiol.*, 1907, xix. 285; and Mancini, *Il Policlinico*, 1906, xiii., Sez. Prat. 173 (abstract in *Archiv f. Verdauungskrank.*, 1907, xiii. 326).

not on the gelatin. Their value in acid dyspepsia has already been mentioned.

The cost of gelatin depends entirely on the source from which it is derived, and for ordinary purposes commercial gelatin is the most economical. It has been calculated that it costs sixteen times as much to prepare jelly from calves' feet as to use commercial gelatin for the purpose (Thudichum). Isinglass is also a costly source, a quart of jelly made of commercial gelatin costing about 6d., whereas if isinglass be used it will cost about 1s. 9d., and it does not even seem to be altogether true that the latter goes further and sets better. The same is true of soups, for it is cheaper to add 7 or 10 grammes ($\frac{1}{4}$ to $\frac{1}{3}$ ounce) of gelatin to ordinary stock if one wants a strong soup than to get the gelatin from boiling up veal. Bones are only a cheap source of it in so far as they cannot be used for any other purpose. The composition of bones is about as follows :

Water	..	..	..	5 to 50 per cent.
Gelatin substance	..	..	..	15 to 50 ..
Fat	..	..	..	$\frac{1}{2}$ to 20 ..
Ash	..	..	..	20 to 70 ..

When boiled in the usual way they yield from $1\frac{1}{2}$ to 7 per cent. of their weight, chiefly in the form of fat. When broken up and treated in a Papin's digester the yield is greater, 3 pounds yielding (according to Smith) as much nitrogen as can be got from 7 pounds of meat, and as much carbon as is yielded by 1 pound under similar treatment. In spite of this, Forster concluded from his experiments on the subject that it is cheaper to use commercial gelatin than to buy bones specially to produce it. Gelatin, therefore, is merely a cheap addition to poor diets in so far as it can be obtained from many materials which would otherwise be wasted, and ordinary jellies can only be regarded as dear foods, for a shilling spent on the 'calf's-foot jelly' of the shops yields only 470 Calories of energy, and no building material at all.

FISH.¹

1. Chemical Composition.—Protein and fat are the chief nutritive constituents found in fish, just as they are in meat. According to

¹ In preparing this section the writer has derived much help from the following publications: 'The Chemical Composition and Nutritive Values of Food Fishes and Aquatic Vertebrates,' by W. O. Atwater, Ph.D., Washington, 1891 (abstract from Report of United States Commissioner of Fish and Fisheries, 1888); and 'Fish as Food,' United States Department of Agriculture, Farmers' Bulletin 85, 1898, by C. F. Langworthy, Ph.D.

the relative proportions of these ingredients present, fish may be conveniently divided into the two groups of 'fat' and 'lean,' or, more exactly, thus:

- (a) Fish with more than 5 per cent. of fat.
Examples: Eel (18 per cent.), salmon (12 per cent.), turbot (12 per cent.), herring (8 per cent.).
- (b) Fish with from 2 to 5 per cent. of fat.
Examples: Halibut (2 up to even 10 per cent.), mackerel (2 up to 9 per cent.), mullet (about 2½ per cent.).
- (c) Fish with less than 2 per cent. of fat.
Examples: Cod, haddock, whiting.

The exact chemical composition of the commoner varieties of fish is shown in the following analyses by Miss Katherine Williams,¹ the results having reference to the fish as prepared for the table:

ANALYSIS OF COOKED (BOILED) FISH AS SERVED AT TABLE.

Fish.	Water.	Protein.	Fat, or Ether Extract.	Ash.
Herring	60'54	26'46	9'96	2'21
Salt herring	46'03	20'98	11'28	11'28
Sprats	75'77	14'03	6'63	1'56
Salmon	65'32	19'64	10'20	1'72
Salmon peal	40'90	24'59	25'97	2'15
Trout	73'58	21'13	2'33	1'74
Smelts	80'73	15'91	1'88	0'91
California salmon	61'90	21'54	13'05	2'16
Eels	61'08	16'68	17'38	6'82
Red mullet	68'26	21'02	7'78	1'72
Roach	75'37	19'49	3'70	0'26
Gurnet	73'77	23'38	0'47	0'93
Mackerel	73'13	16'74	6'91	1'09
Cod	76'32	21'67	0'27	0'76
Salt cod	72'35	21'03	0'26	3'94
Haddock	72'37	21'98	0'36	0'91
Hake	84'88	12'30	0'87	0'57
Whiting	78'78	16'88	0'39	0'41
Turbot	77'84	18'77	1'05	0'51
Brill	62'74	35'00	0'64	1'65
Halibut	74'46	20'34	4'04	1'05
Plaice	79'86	15'13	1'98	0'82
Soles	79'20	18'03	0'35	0'57
Lemon soles	78'11	15'29	2'83	0'97
John Dory	77'89	17'54	0'45	0'19

¹ *Chemical News*, 1911, vol. civ., p. 271.

ANALYSIS OF FLESH OF COOKED FISH.

Fish.	Water in Flesh.	Reducing Substances in Dry Matter as Glucose.	Ash in Dry Substance.	SOLIDS IN DRY SUBSTANCE.		
				N.	Fat.	Protein.
Herrings	60'54	—	5'56	11'11	25'25	67'07
Salt herrings ..	46'03	17'59	19'69	7'12	21'90	38'88
Sprats	75'77	9'88	6'42	9'26	27'37	57'94
Sardines	44'35	—	12'03	8'54	33'49	55'44
Salmon	65'32	14'89	4'94	10'70	29'43	56'65
Trout	73'58	4'68	6'60	11'96	8'84	80'00
Eels	61'08	8'91	2'11	7'36	44'68	42'88
Mackerel	73'13	13'93	4'07	10'46	25'73	62'32
Cod	76'32	6'67	3'31	15'30	1'15	91'55
Salt cod	72'35	7'14	14'26	12'41	0'94	76'06
Haddock	72'37	13'15	3'28	13'11	1'29	79'57
Whiting	78'78	17'54	1'92	13'28	1'86	79'55
Turbot	77'84	11'81	2'41	13'76	4'75	84'71
Halibut	74'46	—	4'11	13'32	15'81	79'67
Plaice	77'86	11'56	4'06	13'02	9'84	75'16
Soles	79'20	11'87	3'47	14'00	1'71	86'71
Lemon soles ..	78'11	14'80	4'42	11'04	12'96	69'88
Oysters	77'71	18'32	12'16	11'85	7'77	65'42
Smelts	80'73	2'17	4'73	11'61	9'76	82'59
Red mullet ..	68'26	9'79	5'43	11'59	24'52	66'26
Roach	75'37	6'28	1'08	13'03	15'03	79'14
Gurnet	73'77	14'77	3'53	14'24	1'81	89'16
Tunny	63'49	—	5'52	10'55	30'68	66'08
Hake	84'88	13'64	3'90	12'86	5'67	81'36
John Dory ..	77'89	14'29	2'06	13'32	8'52	79'53
Brill	62'74	—	4'42	15'49	1'62	93'95

In the following table the composition of some of the commoner varieties of fish in the fresh state is represented in a more convenient form than in the above :

COMPOSITION OF FISH.¹

	Water.	Protein	Fat.	Ash.	Fuel Value per Pound in Calories.
Cod	82'6	16'5	0'4	1'2	325
Eel	71'6	18'6	9'1	1'0	730
Flounder	84'2	14'2	0'6	1'3	290
Haddock	81'7	17'2	0'3	1'2	335
Halibut	75'4	18'6	5'2	1'0	565
Herring	72'5	19'5	7'1	1'5	660
Mackerel	73'4	18'7	7'1	1'2	645
Mullet	74'9	19'5	4'6	1'2	555
Salmon	64'6	22'0	12'8	1'4	950
Smelt	79'2	17'6	1'8	1'7	405
Trout (river) ..	77'8	19'2	2'1	1'2	445
„ (salmon) ..	70'8	17'8	10'3	1'2	765
Turbot	71'4	14'8	14'4	1'3	885

¹ Compiled from analyses in the 'Chemical Composition of American Food Materials,' by Atwater and Bryant, Bull. No. 28 (revised edition), U.S. Department of Agriculture, Office of Experiment Stations, 1899.

To these may be added some recent analyses of preserved fish and of sardines in oil:

PRESERVED FISH.¹

	Water.	Nitrogenous Matter.	Fat.	Ash.	Salt.
Dried cod ..	16·16	81·54	0·74	1·56	
Salt mackerel ..	44·45	19·17	22·43	13·82	11·42
„ herring ..	46·23	18·90	16·89	16·41	14·47
Smoked herring	69·49	21·12	8·51	1·24	

SARDINES IN OIL.²

Source.	Water.	Fat.	Proteid.	Ash.
Sicily	50·16	12·68	4·30	7·51
Tunis	50·36	13·07	4·07	7·85
Sardinia	40·66	23·75	3·83	8·98

Some points in these analyses are deserving of comment. The first thing to notice is the large amount of waste matter, in the form of skin, bones, etc., which fish contains. In fish, as sold, the waste may amount to fully 70 per cent., while even in fish as served at table it may be as high as 35 per cent. Another noteworthy point is the large amount of water in the flesh of the leaner varieties of fish—considerably more than in lean meat. Lastly, the relative proportions of the nitrogenous constituents are different from those in meat, fish containing more gelatin (about four to three in meat) and fewer extractives. Its greater richness in gelatin-yielding substance causes fish to lose more on boiling than meat does, and is one reason why boiling is by no means the best method of cooking fish (see p. 400). Its property in extractives is the cause of its lack of flavour as compared with meat, and makes a fish diet apt to prove monotonous.

2. *Digestibility of Fish.*—*Artificial experiments* outside the body on the digestibility of fish have yielded discordant results. Popoff³ arrives at the surprising conclusion that fat fish are more easily digested than lean; while ‘smoking’ actually increased the rate of digestion, prolonged cooking, on the other hand, rendering it slower. He gives the following table of the relative quantities digested in a given time:

Meat, raw	100	Eel, smoked	91
„ boiled	83	Sole, raw	66·8
„ smoked	71	„ boiled	60·6
Eel, raw	71	„ smoked	106·1
„ boiled	68		

¹ Marvis is a highly nutritive preparation of the flesh of cod in a dried form which has been lately put again upon the market (The Marvis Co., Ltd., Forth St., Edinburgh).

² *Journal of Chemical Society*, vol. lxxii., 1897, part ii., p. 335.

³ *Zeit. für Physiolog. Chem.*, 1890, xiv. 524.

Chittenden and Cummins,¹ using a very similar method, got quite different results, for in their hands the fat fish proved less digestible than the lean, with the exception of mackerel, which was rather quickly dissolved. They found that the digestibility of fish in general was below that of beef, but several kinds were as easily digested as lamb or mutton. Cod, though containing very little fat, proved to be one of the most indigestible of the fishes they examined.

Penzoldt² employed a more natural method of experiment, fish being eaten in the usual way, and the time which elapsed before it had completely disappeared from the stomach noted. He found that 7 ounces of white fish were digested in two and a half to two and three-quarter hours, while a similar quantity of beef-steak required three and a quarter hours. Salt fish offered more resistance to the action of the stomach, 7 ounces of salt herring requiring four hours for its digestion.

It must be admitted that the results of the last observer are more in harmony with those of everyday experience, which teaches that the lean fish are better borne by the stomach than the fat, and are apparently more easily digested than an equal quantity of meat. It is quite likely that fat interferes with natural digestion much more than with an imitation of the same process carried out *in vitro*: for not only does fat seem to arrest the natural secretion of gastric juice (p.419), but the fat found in fish seems also to be particularly apt to become rancid and affect the stomach injuriously in that way. That white fish should be more easily dissolved by the stomach than beef is only what one would expect from its shorter fibre. This is specially evident in such fish as the whiting, which on that account has been fancifully described as 'the chicken of the sea,' and is frequently recommended, and probably with reason, to the dyspeptic and convalescent. Cod seems to be an exception, having a coarse fibre, and its comparative indigestibility, as found by Chittenden and Cummins, is by no means in contradiction with actual experience (Pavy). The slow solution of salt fish is fully explained by the hardening of the fibres which salting produces.

The absorption of fresh and smoked fish in the intestine takes place quite as well as that of meat, about 95 per cent. of the total solids, 97 per cent. of the protein, and 90 per cent. of the fat entering

¹ *American Chemical Journal*, 1884-85, vi. 318.

² *Deut. Archiv für Klin. Med.*, 1893, li. 535.

the blood (Langworthy). Salted and dried fish are not quite so well absorbed.¹

Nutritive Value of Fish.—The value of fish as a source of energy depends entirely on the amount of fat which it contains. The fat fish, such as salmon, are fully equal to moderately fat meat in this respect, while the lean fish, owing both to the absence of fat and the presence of more water, are of considerably lower nutritive value. It may be reckoned that $1\frac{1}{2}$ pounds of cod or other white fish are only equal in nutritive value to 1 pound of lean beef.²

As a source of building material, fish is somewhat inferior to lean meat, owing to the smaller amount of protein which it contains. This statement applies more strongly to lean fish than to the fatter varieties. Owing to this smaller proportion of protein, and in part also, in all probability, to its lesser richness in extractives, fish seems to be a less stimulating food than meat, and on that account is sometimes recommended as a substitute for the latter in the dietary of epileptics. For the same reasons, white fish may sometimes be used with advantage instead of meat by sedentary persons, and in hot weather.

Two special qualities are erroneously attributed to a fish diet by popular fancy. I refer to the beliefs (1) that fish is specially valuable as a 'brain food,' (2) that it possesses aphrodisiac qualities.

The former of these opinions is grounded on the belief that fish is specially rich in phosphorus, and the way in which the fallacy became promulgated is of some interest. I have already referred to the dictum of Büchner, that without phosphorus thought is impossible (p. 41). The Swiss naturalist Agassiz, knowing this dictum, and being informed by the eminent chemist Dumas that fish contained much phosphorus, put two and two together, and concluded that fish would be specially good for the brain. But we have already seen that the aphorism of Büchner is not altogether true, and there is, further, no justification at all for the statement that fish is rich in phosphorus, and thus the belief that it is peculiarly adapted for the nourishment of the brain, being founded on a double fallacy, falls to the ground.

The second belief, which attributes to a fish diet special stimulating powers on the genetic faculty, has been widely entertained, and is advocated at some length by Brillat-Savarin in

¹ Slowtsoff, *Zeit. f. Physik. und diät. Therapie*, 1910, xiv. 22.

² Rosenfeld ('Der Nahrungswert des Fischfleisches,' *Zentralb. f. inn. Med.*, 1906, xxvii. 169) concludes, as the result of metabolism experiments, that fish is a valuable source both of protein and energy, and can be recommended to the poor as a substitute for meat.

his well-known book. There is, however, no sufficient evidence in favour of this opinion, and it is contradicted, as Pereira has pointed out, by the fact that maritime populations are not specially prolific.

The impression that fish-eating produces a liability to certain diseases of the skin, and especially to leprosy, is founded on somewhat more scientific data, and has been adopted by some eminent authorities, but the discussion of the subject cannot be undertaken here. One practical outcome of this belief has been the abolition of fish from the dietary of the patients in the St. Louis Hospital for Skin Diseases in Paris.

Economic Value of Fish.—In the case of fish, even more than in that of most foods, the market-price is no indication of the true economic value. I have already illustrated this fact by pointing out (p. 17) that although such fishes as haddock and sole are of practically the same nutritive value, yet the price of the latter may be four or five times that of the former. On the other hand, it by no means follows that none of the dearer varieties of fish is worth the money. Salmon, for example, contains nearly three times as much nutriment as an equal weight of cod, and thus a pound of the former at 1s. 6d. may not really be any dearer than a pound of cod at 6d. The amount of waste in fish is also of great importance from the economic point of view. We have seen that the inedible parts of fish as purchased may amount in some cases to as much as 70 per cent. of the whole, and allowance must be made for this in calculating the real cost. For this reason it may be worth while to pay a rather high price for canned or tinned fish, for in these preparations almost the whole of the material paid for is in an edible form.

As a general rule, it may be said that the cheaper varieties of the fat fishes offer most nutriment for any given sum. Salted white fish probably rank next to these. An average herring contains about 15 grammes of edible protein (nearly $\frac{1}{2}$ ounce) and from 5 to 10 grammes of fat, and it has been truly remarked by Dr. Smith¹ that the despised bloater 'offers the largest amount of nutriment for a given sum of any animal food,' and two salt herrings contain as much animal protein as need enter into the daily dietary of an ordinary working man.

The justice of these remarks is borne out by the following calculations, taken from several made by Langworthy,² English prices being substituted for American :

¹ 'Foods,' p. 110.

² 'Fish as Food,' p. 18

COMPARATIVE COSTS OF PROTEIN AND ENERGY AS FURNISHED BY DIFFERENT KINDS OF FISH.

	Price per lb.	Cost of Protein per lb	Cost of 1,000 Calories of Energy.
	d.	s. d.	s. d.
Cod.. ..	3	3 11	2 0½
Halibut	9	4 9	1 7
Salt cod	3½	1 10	0 11
Salt mackerel	5	2 10	0 5½
Tinned salmon	6	2 3½	0 6½
Round of beef	7	3 2½	0 8
Milk 3d. per quart.		3 9½	0 4½

The greater cheapness of the salt fish, and especially of those which are also fat, is at once manifest.

Of the 'offal' of fish, the ovary, or roe, is alone commonly eaten. The roe of the sturgeon, when highly salted, constitutes *caviare*, the best forms of which come from Astrachan. Good *caviare* should be of a grayish colour—not black—and one should be able to make out the separate eggs in it quite easily. It is packed in vessels made of lime wood, as it is very apt to take up foreign flavours, and of these lime wood is destitute. The composition of *caviare*—and approximately of all fish-roe—is as follows (Langworthy):

Water	38·1 per cent.
Protein	30·0 "
Fat	19·7 "
Other non-nitrogenous matters	7·6 "
Mineral matter (including salt)	4·6 "
Fuel value per lb.	1,530 Calories.

The proteins contain a good deal of nuclein, the significance of which as an article of diet has already been mentioned (p. 72).

Three ounces of raw salted *caviare* are digested in about two hours.

The *milt* is the organ in male fish corresponding to the roe, and resembles the latter very closely in composition and nutritive value.

The lobster, crab and other crustaceans, the molluscs, such as the oyster and mussel, and the turtle and frog amongst reptiles and amphibians, may conveniently be considered at this point.

The lobster and crab both consist of two distinct parts: the flesh, which is contained in the claws and tail; and the body, which is mainly made up of liver. The general composition of these parts is thus contrasted by Payen:

	Flesh.	Body.
Water	76·6	84·31
Protein	19·17	12·14
Fat	1·17	1·14

König gives the composition of *potted lobster* as follows :

Water	..	..	..	..	51.33
Nitrogenous matter	..	..	..	..	14.87
Fat ..	..	..	..	..	24.86
Other non-nitrogenous matter..	..	..	..	..	4.04
Ash	..	..	..	..	4.90
Salt	..	..	..	..	0.38

That of *tinned lobster* is (Langworthy) :

Water	..	..	..	..	77.8
Protein	..	..	..	..	18.1
Fat ..	..	..	..	..	1.1
Carbohydrates	..	..	..	..	0.6
Mineral matter	..	..	..	..	2.4

The composition of the crab is practically the same.

The flesh of the lobster and crab is rather indigestible, mainly on account of the density and coarseness of the fibres and the thickness of their walls. The use of vinegar helps to soften the fibres, besides neutralizing ammoniacal salts, which are apt to be present.

The body of these animals is also prone to disagree, not only from the fat which the liver contains, but also, apparently, from the occasional development in it of irritant poisons.

Three ounces of potted lobster require about two and a half hours for digestion in the stomach.

The **oyster** is the most typical and popular of the molluscs. Chemically it contains within itself representatives of all three nutritive constituents of the food :

AVERAGE COMPOSITION OF OYSTERS (Langworthy).

(EXCLUSIVE OF LIQUID.)

Water	..	..	..	..	88.3
Nitrogenous substances ..	..	..	..	..	6.1
Fat ..	..	..	..	..	1.4
Carbohydrates	..	..	..	..	3.3
Salts	..	..	..	..	1.9

The proportion of solid nutriment, however, is not large, three dozen moderate-sized oysters having only from $2\frac{3}{4}$ up to $5\frac{1}{2}$ ounces of solids. It is probable, too, that the nitrogenous matter which they contain is not all in the form of protein, but is partly present as other compounds of lower nutritive value.

Glycogen is the form in which carbohydrate is present in oysters. It is contained in the liver. Its presence renders oysters an un-

suitable food in cases of diabetes in which a strict diet is being enforced.

The oyster is rightly regarded as an easily-digested food—at least, if taken raw. Three medium-sized oysters are entirely disposed of by the stomach in one and three-quarters hours. Cooking renders them tough and less easily digested.

The nutritive value of oysters is not high. A dozen Ostend oysters contain about 5 grammes of digestible protein and $1\frac{1}{2}$ grammes of fat. It would take fourteen of them to contain as much nourishment as one egg, and 223 to equal a pound of beef (Stutzer). It is therefore not surprising to hear of enormous quantities of oysters being occasionally consumed at a sitting. Brillat-Savarin relates that he was acquainted with a man who used to eat a gross of them at a time, and follow that up by a heavy dinner! They are an extravagant form of food, for a given quantity of protein costs about three times as much in the form of oysters as it does if purchased as beef.

In recent years oysters have to some extent fallen into disfavour, from the belief that they may be the means of conveying the infection of typhoid fever. The belief is not unwarranted, for if oysters are grown in estuaries they might easily enough become infected with typhoid germs derived from sewage, and it has been found by artificial inoculation that typhoid bacilli thus introduced are capable of surviving in the body of the oyster for several days.¹ The risk, however, can be avoided by keeping the oysters alive for a day or two in salt water which is frequently changed. This washes them out and destroys the bacilli. Cooking effects the same object with greater certainty, but at the cost of diminished digestibility.

The 'greening' of oysters is another subject which has recently attracted a good deal of attention. From their investigations into the cause of this phenomenon, Herdman and Boyce have concluded that there are several kinds of greening, some of which, such as that found in the green Marennes oysters and in those of several rivers on the Essex coast, are healthy; while in others, such as some Falmouth oysters, the green colour is associated with the presence of an excess of copper. Others, again, such as some American varieties re-embedded on our coasts, have a pale green leucocytosis, and cannot be regarded as in a healthy state.

¹ Herdman and Boyce, 'Lancashire Sea Fisheries,' Memoir I. : 'Oysters and Disease.'

Langworthy's investigations¹ led him to a somewhat different conclusion, for he regards 'greening' as the result of the consumption by the oyster of certain forms of green algæ, the colouring matter of which is soluble in the tissues and juices of the oyster, and apparently harmless.

After being removed from the sea, oysters are sometimes 'floated' in brackish water, with the object of 'fattening' them. It has been found, however, that the apparent increase in plumpness of the oyster under this treatment is really due to the inhibition of moisture by osmosis, and that they actually lose from one-eighth to one-fifth of their nutritive value in the process.²

The composition of mussels, clams, periwinkles, scallops and other molluscs is very similar to that of the oyster, and, like the latter, they cannot be regarded as foods of important nutritive value. They are also peculiarly liable to develop poisons which may produce serious, and even fatal, symptoms, and in susceptible persons their use is sometimes followed by irritation of the skin, usually taking the form of nettle-rash.

The green turtle is almost the only reptile used for food in this country, and that chiefly in the form of soup. It is called green because its fat has a greenish colour, which, according to Sir Hans Sloane,³ imparts a yellow tint to the sweat of those who partake largely of it. In preparing the soup, the dorsal and ventral shields are removed, scalded to remove the scales, and then boiled till the bones separate. The liquor forms the stock. The softer parts of the shield are then cut into oblong pieces, which constitute the so-called lumps of green 'fat'—really a species of gelatin. Sun-dried turtle forms a soup of equal nutritive value, and at a considerably lower cost, while the basis of mock-turtle is the gelatinous substance in the scalp of the calf. From a strictly nutritive point of view, turtle soup is certainly not worth a tenth of the price paid for it.

Frogs' legs are but rarely seen in this country, though common articles of diet on the Continent. They are derived from the large edible frog (*Rana esculenta*), and, though easily digested and of a delicate flavour, are not of high nutritive value.

The average chemical composition of the different groups of foods studied in this chapter is represented in the following diagram,

¹ 'Fish as Food,' p. 17.

² *Ibid.*, p. 16.

³ See Pereira, 'On Food and Diet,' p. 273.

which also gives some idea of their relative nutritive values. It is constructed from the analyses published by Langworthy.

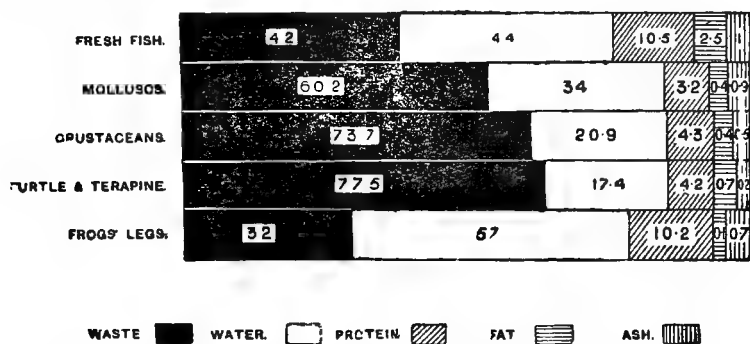


FIG. 7.—COMPARATIVE COMPOSITION OF FISH AND THEIR ALLIES.

CHAPTER VI

SOUPS, BEEF-EXTRACTS, BEEF-JUICES, BEEF-TEA, AND
BEEF-POWDERS

WHEN meat is cut up and placed in water for the purpose of making soup, there is dissolved out of it (1) a small proportion of its soluble proteins; (2) a large part of its extractives and mineral matter; (3) a small quantity of fat. If the water is now raised to the boiling-point, the protein is coagulated and floats to the top as a brownish 'scum,' which is usually carefully skimmed off. At the same time the proportion of extractives and mineral matter in the solution is increased, and some of the connective tissue is dissolved out in the form of gelatin.

It will be evident from these considerations that a clear soup contains chiefly the *flavouring* constituents of the meat from which it is prepared. The amount of nutritive matter in it is very small, for a solution of gelatin of even 1 per cent. strength 'sets,' and very few soups contain as much as that. This estimate of the nutritive value of a clear soup is borne out by the following example:¹ 1 pound of beef and about $\frac{1}{3}$ pound of veal bones were boiled down in the usual way, and yielded 1 pint of strong soup. Analysis of this showed that it contained 95 per cent. of water and only 5 per cent. of solids, made up in almost equal proportions of fat, gelatin, and extractives, along with a small proportion of mineral matter. And yet this was a *strong* soup. Most clear soups contain only from $1\frac{1}{2}$ to $2\frac{1}{2}$ per cent. of solids. As an ordinary soup-plate holds, when full, about 7 ounces, a large helping of the above strong soup would only yield to the consumer about $\frac{1}{3}$ ounce of solid matter, and even of that only the gelatin and fat, say about $\frac{2}{3}$ ounce, are really 'foods.'

Seeing that it is chiefly the flavouring materials of the meat which

¹ Atwater, 'Chemistry and Economy of Food,' p. 85.

are removed in making soup, it is obvious that we cannot get a good soup and a well-flavoured dish of meat from the same piece of beef. You cannot both eat your cake and have it; and although it is true that the meat, after the soup is made, has lost practically none of its nutritive qualities, yet its sapid and appetizing elements are gone.

If, then, one wants to make soup nourishing, one must simply use it as a vehicle by means of which other food materials added to it can be conveyed into the stomach. Starchy materials are often added in this way, cornflour being, perhaps, one of the commonest. Barley is similarly used in barley broth. In potato soup, too, the soup is simply a vehicle for a considerable amount of potato starch. In other cases nitrogenous matter is added, such as grated cheese or macaroni (which contains a good deal of gluten), or the soup is thickened by the addition of one of the pulses, *e.g.*, peas or lentils, the latter being amongst the most nutritious soups. Animal matters may be also be employed, as in the preparation of purées of chicken, fish, or game. The following analyses of two **thick soups** are taken from König :

	Water.	Nitrogenous Matter.	Fat.	Other Nitrogen- free Substances.	Cellu- lose.	Mineral Matter.
Pea soup ..	88·26	3·38	0·93	5·60	0·70	1·13
Potato soup	90·96	1·37	1·53	4·87	0·26	0·99

Even in these cases the nutritive value cannot be regarded as high, for half a slice of bread would contain as much solid matter as a full plateful of such a soup.

It must not be supposed, however, that clear soups are of no dietetic value. It is not an error to begin dinner with soup. It has been found that it is just those very materials (extractives and gelatin) which a clear soup contains which are most calculated to promote a flow of gastric juice, and so to further the complete digestion of the solid food subsequently introduced into the stomach. As a French writer has said, soup should be to a dinner what the overture is to an opera or the porch is to a house. It is a good introduction. If, then, one gets the choice of 'clear' or 'thick,' it may be well, if a solid meal is to follow, to select 'clear'; but if the soup itself is to be the *pièce de résistance*, one should certainly choose 'thick.' For this reason, when soup is served out at penny dinners or soup-kitchens, it should always be made as thick as possible, preferably by the addition of one of the pulses, such as lentils or peas. In the case of an invalid, a 'strong soup' may be a useful means of rousing

the appetite and stimulating the digestive powers of the stomach, but it cannot be regarded in itself as a serious contribution to his nutrition.

BEEF-EXTRACTS.

The valuable culinary qualities of an extract of meat were first recognised by Proust, but it was not until the matter was taken up by Baron Liebig that they became at all widely known.¹ The extract was first prepared on a commercial scale by the company authorized by Liebig in the year 1865. The factory was established in South America, as cattle can be obtained there much more cheaply than in Europe.

The method of preparation is simple. The fresh meat is simply chopped up, heated under pressure with a little water, the extract filtered and evaporated *in vacuo* and in the open. The product is the brown, sticky material with which everyone is familiar. A good sample should have a rather golden-brown colour. If too dark, it has probably been burnt, and it should have a strong and agreeable 'meaty' odour.

Liebig calculated that 34 pounds of pure beef should yield 1 pound of the extract, and that this should make 70 pints of beef-tea, every pint therefore corresponding to $\frac{1}{2}$ pound of beef. He fixed the composition of the article to be sold thus :

Moisture may vary from	..	..	..	16 to 21 per cent.
Mineral matter may vary from	..	..	..	18 " 22 "
Extractives may vary from	..	..	..	56 " 60 "

Liebig expressly forbade the sale of any extract containing gelatin. The latter substance is so cheap, he said, that it would tempt people to add it as an adulteration, and would also prevent the extract from keeping. It would then sink to the level of 'tablets of consommé,' which he regarded as 'a kind of coloured glue.' He likewise discountenanced the addition of any salt.

It will be observed that into the composition of Liebig's extract as fixed by its inventor no proteins or albuminoids enter. A vast number of analyses, however, have been made of it in more recent times, some of which have credited it with containing these valuable nutritive constituents in considerable amount. Amongst the most striking of these is an analysis by Kemmerich,² which yielded the following results :

¹ See Thudichum, 'Origin, Nature, and Uses of Liebig's Extract,' London, 1869.

² *Zeit. für Physiolog. Chemie*, 1894, xviii. 409.

Composition of Liebig's Extract according to Kemmerich.

Water	18 per cent.
Proteins	} 30 "
Gelatin	
Extractives	25 "
Mineral matter	20 "
Ether extract, etc.	7 "

This was certainly a very startling result, but it was not allowed to go long unchallenged, for König and Bömer¹ have submitted the above analysis to a searching criticism, and have shown, and I think conclusively, that it was arrived at by faulty methods. They point out that one could not *a priori* expect Liebig's extract to contain much gelatin, for heat is only employed in its preparation to a small extent, and, further, solutions of it do not gelatinize. They show that it contains only about 7 per cent. of albumoses, and perhaps traces of peptone, but certainly not more than 1 per cent. of gelatin, and distribute the amount of nitrogen which it contains thus:

Total nitrogen	9.28 per cent.
Nitrogen in the form of soluble albumin	Trace
Albumoses	0.96 per cent.
Peptone	Nil to a trace.
Meat bases	6.81 per cent.
Ammonia compounds	0.47 "
Other nitrogen compounds	0.83 "

More recent analyses of Liebig's extract ('Lemco') by the *Lancet*² gives the following as its range of composition:

Moisture	From 17.12 per cent. to 21.50 per cent.
Mineral salts	18.35 " 26.30 "
Organic matter	55.34 " 62.43 "
Total nitrogen	9.48 " 11.62 "
Albumose	8.52 " 14.26 "
Peptone	3.34 " 5.60 "
Total proteins	14.12 " 19.34 "
Creatin and creatinin	9.00 " 12.50 "
Insoluble matter	0.25 " 0.88 "
Sodium chloride	2.68 " 5.69 "
Phosphoric acid (P ₂ O ₅)	3.06 " 6.70 "

Although, therefore, small amounts of albumose and peptone are present, it is upon the extractives that the uses and value of the extract must chiefly depend, and for that reason we must now look a little more closely at their chemical and physiological properties.

¹ *Zeit. für Analyt. Chemie*, 1895, xxxiv. 548.

² Report of Special Commission upon the Origin, Manufacture, and Uses of Extract of Meat, *Lancet*, 1908, ii. 1233.

On the chemical properties of the extractives of meat we have but scanty information. Most of them are basic substances; a few are amides. Creatin, xanthin, carnine, and the peculiar and interesting substance carnic acid, which seems closely to resemble the so-called 'anti-peptone,' are amongst the best known. These substances represent the fragments, as it were, of broken-down protein, and are of no use as tissue-builders.

They bear very much the same relation to protein as sand does to the sandstone out of which it has been crushed, and it is as hopeless to expect to build up tissues from them as it would be to construct a house out of sand. They are also incapable of being oxidized in the body, and so are useless as sources of heat or energy. Being neither tissue-builders nor energy-producers, they cannot be regarded as foods. Experiment confirms this, for it was found that rats which were fed on 4 grammes of meat-extract daily died quite as soon as other rats which got no food at all, and Jessop¹ quotes a writer who consumed half a pot of Liebig's extract at a sitting, and yet felt as hungry as ever afterwards.

To do Liebig justice, he recognised this himself. 'Meat-extract,' he says somewhere, 'cannot make us strong, but it makes us aware of our strength.' We have here introduced the notion that the extractives of meat act as 'stimulants,' a view which has since been frequently maintained. It must be admitted, however, that satisfactory evidence for any belief in the 'stimulating' properties of beef-extract is not forthcoming. A 'stimulant' must act either on the heart, quickening and strengthening its action, or upon the central nervous system, abolishing or lessening fatigue. Now, it has been shown that 2 ounces of Liebig's extract can be taken at one time by a healthy man without the production of any effect other than slight diarrhoea.² Certainly no increase in the rapidity or force of the pulse was observed.

Of course, if the extract be taken, as it usually is, dissolved in hot water, the heart's action may easily be increased, but the sipping of hot water by itself is quite capable of producing such an effect. On the other hand, the danger of any depression of the heart from the action of potash salts contained in the extract seems to have been greatly exaggerated. It has been conclusively shown that even large doses of potash salts have no effect on the pulse.³

¹ *Brit. Med. Journ.*, 1889, ii. 462.

² See Lehmann, *Archiv. für Hygiene*, 1885, iii. 249; and Bunge, *Pflüger's Archiv.*, 1871, iv. 234.

³ See Bunge and Lehmann (*loc. cit.*): 100 grammes of meat boiled for three hours yielded 2·87 grammes of extract with 0·37 gramme of potash salts.

As regards an influence on the nervous system the evidence is equally unsatisfactory. There is no proof that the extractives of meat act as brain stimulants in the way that tea and coffee do, but there is some evidence¹ that they are capable of removing the effects of muscular fatigue, so enabling an exhausted muscle to become active again. This may explain the beneficial effects which seem sometimes to follow the administration of beef extract in fatigue.

It has been suggested that the action of the extractives in diminishing fatigue is comparable to the use of oil in machinery. 'Friction' is lessened and effort rendered easier. It must be remembered that this is a mere suggestion, unsupported by any definite evidence, but at the same time one has to face the fact that clinical observers have repeatedly affirmed the refreshing qualities of a solution of the extractives of meat. 'What more invigorating remedy, more powerfully acting panacea,' says Proust, 'than a portion of genuine extract of meat, dissolved in a glass of noble wine?'

Whilst the stimulating properties of the extractives of meat must be regarded as somewhat doubtful, there can be no question at all of their marked effect on the digestive organs. The experiments of Pawlow have shown that they are the most powerful exciters of gastric secretion that we possess. They are thus eminently calculated to rouse appetite and aid the digestion of any food with which they may be taken. This, indeed, is their true function, both in health and disease. They are flavouring agents, and their proper place is in the kitchen, not by the bedside. As Voit has rather fancifully put it, the influence of such substances as the extractives of meat on the nervous system is mainly an æsthetic one, and is comparable to the influence of a symphony by Beethoven on the ear, or of a picture by an old master on the sense of sight.

Professor Thompson² showed that the addition of a small amount of beef extract to the diet leads to an increase of weight both in men and animals, and to a rise in the retention of nitrogen in the body. Whether these results are to be ascribed solely to an improvement in digestion and absorption, or whether the beef extract contains some substance (? a vitamine) which exercises a specific effect upon metabolism is uncertain, but at all events the experiments are highly interesting and important.

We may conclude, then, that Liebig's extract, though containing too little protein matter to be in itself a food, may act as a valuable adjuvant to other foods, especially where appetite and digestion are

¹ See Kobert, *Archiv für Exper. Path. und Pharmac.*, 1882, xv. 60.

² *Brit. Med. Journ.*, 1911, ii. 613.

feeble. The possible value of the salts which it contains will be discussed when we consider beef-tea.

What is meant, then, or ought to be meant, when one says that 1 pound of the extract is the equivalent of 34 pounds of meat, is that it contains all the *flavouring* ingredients of the latter. It does not in any sense contain the *nutritive* matter of that quantity of meat. As one might have expected, the fact that Liebig's extract is of very small nutritive value was not long in being recognised, and numerous rival preparations have sprung up which profess to contain, in addition to the flavouring ingredients of meat, some or all of its nutritive constituents. These are made by adding to the watery extract obtained from the meat a proportion of the meat fibre which is left behind. In no case, however, does the whole of the fibre of the meat seem to be returned to the extract. The reason why one believes this is clearly stated by Allen.¹ 'In the lean of meat the proteins bear to the sum of the extractives, meat bases and salts the proportion of about 4 to 1. Hence, if all the meat fibre, etc., were again added to the extract, the product would contain the solids of meat in the same relative proportions. Assuming in a preparation the presence of 70 per cent. of extractives, etc., and 10 per cent. of meat fibre, it follows that only about 1 part out of 28 parts of fibre separated has been returned to the extract.' That the proportion of proteins to extractives and mineral matter in most of these preparations is really not much greater than 1 to 7 will be evident on an inspection of the analyses in the table on p. 97.

It will be observed that the proportion of insoluble protein—i.e., meat fibre—is not really high in any of these preparations, whilst the amount of soluble proteins is no greater than it is in ordinary meat extract. As regards meat 'Essences'—e.g., Brand's—the percentage of water is so high that the nutritive value of the preparation is almost negligible, and depends entirely upon small quantities of soluble proteins and gelatin. The same is true of 'chicken jelly' and similar products which are so largely used in the sick-room. They are mildly stimulating, and tend to promote appetite, but their contribution to the nutrition of a patient is negligible. When one adds to that the consideration of their expense, it will be realized that they are essentially luxuries, and are not to be regarded as in any respect necessary adjuncts of invalid cuisine. They have the advantage, however, as compared with ordinary meat extracts, of containing less salt and other mineral matters, and can thus be taken in larger quantities without causing thirst or diarrhoea, or throwing a strain upon the kidneys.

¹ 'Commercial Organic Analysis,' iv. 304, footnote (2nd edit.).

COMPOSITION OF BEEF-EXTRACTS, ETC.¹

	'Oxo.'	Nursing 'Oxo.'	Bovril.	Invalid Bovril.	Brand's Essence.	Armour's Extract.	Jardox.
Water ..	39'71	23'27	38'10	21'82	87'17	24'30	22'50
Insoluble protein	4'61	5'83	8'40	21'42	—	1'58	8'32
Albumoses and peptone	13'50	33'51	3'84		10'4 (5 = gelatin)	14'50	12'50
Extrac- tives, etc. }	24 14	21'7	31'79	39'60	1'01	40'56	15'00 (nitrogenous)
Mineral matter	18'04	15'73	17'87	17'16	1'39	19'03	16'51 (non-nitrogenous)
							19'07

Bovril is one of the best known of the preparations which contain meat fibre. The composition of its solid matter, compared with the solid matter of lean meat, is thus given by Voit:²

	<i>Bovril (Dried).</i>					<i>Meat (Dried).</i>
Organic matter	75'3	94'6
Mineral matter	24'7	5'3
Proteins	49'7	86'7
Extractives	25'6	7'8

Voit concludes that only a small part (6 per cent.) of meat fibre has been added to the extract in this case.

Whilst the title of 'food' cannot be denied to these preparations, seeing that they do contain a certain amount of protein, yet they are only foods in theory. Practically, they cannot be taken in sufficient quantity to enable them to be really able to contribute to nutrition. Even in the case of Bovril, a full teaspoonful only contains as much protein as $\frac{1}{2}$ ounce of meat, and it would require about 14 ounces of such a preparation to supply an invalid with the amount of protein he requires daily; but such a quantity he would find it impossible to consume, owing to the enormous quantity of salts and extractives which it would contain. As a matter of fact, the white

¹ This table contains analyses collected from various sources. Where more than one analysis of any preparation exists, that which seemed most trustworthy has been selected. The results, however, must be regarded as merely approximate, absolute accuracy in the analysis of these preparations being hard to attain owing to technical difficulties in the separation of the different constituents. This may help to explain the very discordant results often arrived at by different investigators. For further analysis of these and similar preparations, see Allen's 'Commercial Organic Analysis,' iv.; Chittenden (*Medical News*, Philadelphia, 1891, lviii. 716), *Food and Sanitation* (1893 and 1896), and Leyden's 'Handbuch der Ernährungstherapie,' Bd. i.

² *Münch Med. Wochensh.*, 1897, xlv. 219.

of one egg will contain as much nutritive matter as three teaspoonfuls of any of the preparations in the above table. I cannot, therefore, think that these preparations are to any practical extent superior to those which contain the extractives only. It is not a question, as Voit says, of whether a preparation contains nutritive matter or not, but of *how much* it contains, and one might as well add a pinch of dried meat to a cup of tea to render it 'nutritious,' or say that air is nutritious because it contains organisms which would in an infinitesimal degree help to feed one, as hope to obtain any real nourishment by the use of such preparations as these. Not only so; the expense of these manufactured articles would alone render their use as foods impossible. One may take it that even the cheaper members of the group would only yield the 80 grammes or so of protein which an invalid requires daily at an outlay of six or seven shillings per day.

Recently, **extracts prepared from yeast** have been introduced as substitutes for ordinary meat extracts. A good example of these is the preparation known as **Marmite**,¹ which has the following composition:

	<i>Per Cent.</i>		<i>Per Cent.</i>
Water	26·84	Proteins	10·50
Nitrogenous extractives	34·67	Mineral matter	26·95

Such preparations resemble beef-extracts so closely in their general characters that they have even been used in the adulteration of genuine meat extracts.² The chief chemical difference between beef-extract and an extract of yeast appears to consist in the presence of creatin and creatinin in the former, and their absence in the latter; yeast extract also contains relatively more of the base adenine.³ Whether these slight chemical differences involve a different action in the body is still undetermined, but there is no reason to believe that yeast extract is in any way unwholesome, although it may, perhaps, not have quite the same stimulating effect on gastric secretion that genuine meat extracts have.⁴

¹ Analysis supplied by the makers.

² For the method of distinguishing yeast extract from genuine meat extract, see papers by A. Searl, F.C.S., in the *Pharmaceutical Journal*, 1903, 4th series, xvii. 516, 704.

³ See a paper by Gamgee ('Are Yeast Extracts justifiable as Substitutes for Extract of Meat?'), *Brit. Med. Journ.*, 1908, ii. 449, and a reply to it by Chapman (*Ibid.*, 1908, ii. 1741).

⁴ Hellner ('Hefe Extracte'), *Zeit. f. Hygiene*, 1903, xlii, 461, and Hoffmann and Wintgen, *Arch. f. Hyg.*, 1907, lxi. 187.

BEEF-JUICES.

Clearly to be distinguished from the beef-extracts is the group of preparations known as beef-juices. As their name implies, these are intended to consist of the 'juice' of meat—*i.e.*, of the fluid substance contained in the muscle fibres. They are prepared by subjecting the meat to strong pressure, and are subsequently concentrated by evaporation *in vacuo*. The use of heat must be carefully avoided in their manufacture, as it would coagulate the soluble proteins contained in the juice. This is what is meant when one reads that such and such a beef-juice 'is prepared by a cold process'; and as the plant necessary to carry out the evaporation is rather expensive, the cost of these preparations is necessarily high. Further, as one would expect, they are liable to undergo putrefaction after manufacture, and this in many of them is guarded against by the addition of some salt or glycerine or other harmless preservative. That they do in reality contain the juice of raw meat is shown by the fact that many of them at least yield the spectrum of oxy-hæmoglobin.

In order better to appreciate the relative values of these preparations, we must first look for a moment at the composition of **natural raw-beef juice** as prepared at home.

Raw-beef juice may be prepared in various ways. One is by the method of expression. If beef be squeezed very hard, juice exudes from it just as it would from an orange. Expression may be carried out at home by means of a lemon-squeezer;¹ but this is a wasteful method, as it only succeeds in removing a part of the total amount of juice. By the use of suitable presses, wholesale manufacturers succeed in obtaining a much larger yield of juice from a given weight of beef.

Another method is the old-fashioned one of cutting the meat into small squares, and placing these in a tightly-corked bottle, which is then immersed in a saucepan of water, which is gradually heated till the water almost boils. The bottle is then left in this hot water for two or three hours. As a result of the heat the meat contracts, squeezing out as it does so a considerable quantity of rich juice. This method is also wasteful, and, unless the heat be carefully regulated, some of the protein in the juice is apt to be coagulated.

¹ The Hercules Patent Meat-Juice Press is a much more efficient apparatus, giving a yield of about 50 per cent.

Perhaps the best method of all is to chop up the meat, and extract the juice from it by the addition of cold water. If the mixture be left to stand for some time in a cool place, the soluble proteins and other constituents of the meat are gradually dissolved out, and are obtained on squeezing out the pulp in muslin. Of course, the juice so obtained is somewhat diluted, but to make up for this one obtains a larger quantity of it. This is certainly the most economical method of procedure.

The following table shows the composition of raw-beef juice obtained by these different methods. The composition of the juice varies somewhat according to the method employed in preparing it, the amount of coagulable protein rising in one case to nearly 7 per cent., while in another it is as low as 2 per cent. The proportion of extractives also varies a little.

In an experiment which I made myself, half a pound of good lean beef was taken and passed through a sausage-machine. Its own bulk of water was then mixed with it, and the whole allowed to stand in a cool place overnight. It was then firmly squeezed

COMPOSITION OF NATURAL RAW-BEEF JUICE.

Method of Preparation.	Water.	Coagulable Protein.	Extractives.
1. Meat from round slightly broiled and pressed ¹	88·1	6·97	3·90
2. Meat from neck slightly broiled and pressed ¹	90·1	5·18	3·56
3. Chopped beef heated in corked bottle ¹ ..	92·1	2·19	2·09
4. Lean steak slightly broiled, and juice expressed with lemon-squeezer (1 lb. yielded 2½ oz.) ²	92·9	2·90	3·40
5. 1 lb. beef and 8 oz. water stood on ice for six hours; then twisted in coarse muslin (yield=8½ oz.) ²	94·9	3·0	1·90
6. 4 oz. minced steak soaked for an hour in 1 oz. water, then forcibly expressed ³	91·1	5·1	3·1

in muslin. Four and a half ounces of juice were thus obtained, containing 5½ per cent. of coagulable protein. This quantity was obtained at a cost of 5d. In this table there is exhibited the composition of most of the beef-juices met with in the market. It will be observed that these also vary considerably in composition.

¹ Bulletin 21, United States Department of Agriculture, p. 96.

² Holt's 'Diseases of Children,' 1899, p. 153.

³ Cheadle's 'Artificial Feeding of Infants' (2nd edit.), p. 115.

COMPOSITION OF BEEF-JUICES.¹

	Valentine's Beef-juice. ²	Brand's Meat- juice. ³	Lipton's Fluid Beef. ⁴	Burgoyne's Meat-juice. ⁵	Wyeth's Meat- juice. ⁶	Armour's Beef-juice. ⁷	Bovril Beef- juice. ⁸	'Bovinine.' ⁹	Armour's Soluble Beef. ¹⁰	'Vitalia.' Meat-juice. ¹¹	'Carnine Lefrancq.' ¹²
Water	51.21	59.15	42.91	49.51	44.87	74.10	52.01	78.42	23.07	66.5	26.88
Protein	9.65 (0.53 coagu- lable)	15.45 (5.28 coagu- lable)	22.13 (6.87 as albu- min)	13.00 (3.71 coagu- lable)	38.01	8.3	7.23	13.32	33.38 (32.05 solu- ble)	21.0	11.77 (4.40 coagu- lable)
Extractives Non-nitro- genous matters	11.16	16.55	18.70	8.10	—	9.54	14.03 20.76 (carbo- hy- drates)	0.55 6.01	13.44 6.75	6.0	0.55 59.56
Mineral matter	10.84	8.85	16.26	14.20	17.12	7.51	5.97	1.60	13.27	6.5	1.24

Of the various ingredients, the coagulable protein is the most important, and, as the amount of this present is not clearly stated in some of the analyses, I have estimated the quantity contained in some of these preparations, the result being embodied in the following table:

AMOUNT OF COAGULABLE PROTEIN IN VARIOUS BEEF-JUICES.

	In 100 Parts by Volume.	In 1 Tea- spoonful.
'Bovinine'	17 per cent.	1.02 grammes.
'Carnine Lefrancq'	5.8 "	0.35 gramme.
Armour's Beef-juice	5 "	0.30 "
Wyeth's Beef-juice	5 "	0.30 "
Bovril Meat-juice	4 "	0.24 "
Brand's Beef-juice	4 "	0.24 "
'Liquor Carnis'	3½ "	0.22 "
'Taurine'	1 "	0.06 "
Valentine's Meat-juice	0.3 "	0.018 "

Bovinine is an American product of dark brown colour, and when examined with a spectroscope shows distinctly the presence in large amount of the altered colouring matter of blood (methæmoglobin). Indeed, Professor Chittenden, who has analyzed it,¹³ is of the opinion that it is prepared largely from blood. It is certainly very poor in

¹ See footnote to Table of Beef-Extracts.

² Analysis by Dr. Candy (unpublished). For other analyses of Valentine's Meat-juice see Chittenden (*Medical News*, Philadelphia, 1891, lviii. 716), *Food and Sanitation* (April 22, 1893), Leyden's 'Handbuch der Ernährungstherapie,' Forster (*Zeit. für Biologie*, 1876, xii. 475).

³ *Ibid.* ⁴ *Lancet* analysis (1898, i. 1407).

⁵ Analysis by Dr. Candy (unpublished).

⁶ *Lancet* analysis (supplied by makers).

⁷ Attfield's analysis (supplied by makers).

⁸ Analysis supplied by Company.

⁹ Hehner's analysis (Allen, *loc. cit.*, p. 309).

¹⁰ Analysis by makers.

¹¹ Analysis by *Lancet*, 1895, ii. 267.

¹² Analysis by Candy.

¹³ *Medical News*, Philadelphia, 1891, lviii. 716.

extractives, and, in my opinion at least, possesses anything but an agreeable flavour. In spite of its cheapness, therefore, and the comparatively large amount of protein which it contains, it is not a preparation to be recommended.

'Carnine Lefrancq' is the juice of raw beef concentrated *in vacuo* without the addition of any preservative other than sugar. It contains nearly 12 per cent. of total protein. A tablespoonful of it represents the amount of juice in 100 grammes of raw meat.

Of the other preparations, Wyeth's, Brand's, and the Bovril Company's juices, and the preparations known as 'Taurine' and 'Liquor Carnis,' all exhibit, on examination, the appearances characteristic of the unaltered colouring matter of blood, and may rightly be regarded as uncooked juices. The amount of coagulable protein which they contain is, however, considerably lower than that in the two preparations mentioned above.

It may be admitted that many of these preparations contain more protein than the natural or home-made beef-juice already described. It by no means follows, however, that they are on that account of higher nutritive value. The objections urged against those beef-extracts which also pretend to be foods apply here with full force. A patient could take considerable quantities of natural raw-beef juice, because it only contains salts and extractives in small amounts; but in many of the artificial preparations the ratio of these ingredients to the total protein is so high that they could only be administered in very moderate quantity without running the risk of exciting diarrhoea and thirst. That *no* raw-beef juice, whether natural or otherwise, can really be regarded as an important aid to nutrition is evident from the fact that, even of a preparation which contains 5 per cent. of protein, about 3 pints would be needed to supply the protein required by an invalid daily. The administration of such a quantity is, of course, impossible. They can only be of some slight service in tiding over a crisis in which the administration of milk is, for some reason or another, impossible. As an example, one might mention cases of vomiting and diarrhoea in young children. One must be careful not to allow oneself to be misled by the examples often adduced of patients who have lived for several days 'on nothing but So-and-so's beef-juice.' Everyone knows that, provided water be freely supplied, most patients are capable of living on nothing but their own tissues for a surprisingly long period. In most of these instances there can be little doubt that the patient's own fat, and not the beef-juice, deserves the credit of his survival.

Another objection to the use of artificial beef-juices is their expense. From the method of their manufacture, as we have seen, this is almost inevitable; but it is well to remember that the nutriment which they contain costs many times more than it would in the form of home-made beef-juice, and in one case, at any rate, fully 200 times as much. It is really pathetic to see poor people in cases of illness paying large sums for so very small a return. In this connection, it is only right to draw attention to the very great value of egg-white as a substitute for raw-beef juice. Egg-white contains 12 per cent. of egg-albumin, and there is no reason to believe that egg-albumin is in any way inferior in nutritive value to the proteins of meat. An egg yields more than an ounce of white, and by adding to this twice its own volume of water, and straining through muslin, one obtains 3 ounces of a clear solution containing 4 per cent. of coagulable protein, or about as much as an average specimen of commercial beef-juice. All that remains is to stir into this a little Liebig's extract, dissolved in a teaspoonful or so of hot water, and there is produced 3 ounces of a solution which can hardly be distinguished from beef-juice, at a cost of little more than a penny, or twenty-four times cheaper than most commercial juices. This preparation can be used under the same circumstances as beef-juice, and has the advantage that it can be given practically *ad libitum*.

We may next turn our attention to ordinary beef-tea. Now, the nutritive value of beef-tea depends entirely on how it is made. If the preparation is carried out in such a way as to insure the extraction of some at least of the protein of the meat, then the beef-tea will have nutritive value; on the other hand, if it is so made that only the extractives and salts of the meat are dissolved out, then it can never hope to rank as a food. Applying our knowledge of the chemistry of meat, it will readily be apprehended that the temperature at which the tea is cooked is the condition which determines whether it will turn out to be a food or not. The *wrong* way to make beef-tea is to bring it quickly to the boil, for that coagulates the protein, and only removes the extractives and salts of the meat. Unfortunately, much of the beef-tea which is presented to sick people has been made in that way, and hence has no real value as a food; it may be 'stimulating,' or anything else one pleases, but a 'food' it never can be. If, however, it be desired to prepare a beef-tea which will contain real nutriment, one should proceed in the following way:

Get some good lean beef, and trim off with a knife any gristle or fat which is adhering to it, and then scrape the meat down thoroughly with the back of the knife so as to tear it into shreds. In this way all the fibres of the meat are removed from the connective tissue which holds them together; and it is these fibres which contain the most nourishing part of the meat. Having placed the fragments of the meat in a jar, add to them some water and mix thoroughly. How much water should be added is a matter of taste. Obviously, if a small quantity of water is taken, the beef-tea will be stronger than if much is used. As a rule, 1 pint of cold water to 1 pound of beef is the proportion recommended. If the mixture is now set aside in the cold for some time, most of the soluble proteins of the meat will be dissolved out along with the extractives and salts. A little salt is sometimes added to the water under the belief that its solvent powers are thereby increased. It is doubtful, however, whether that is really the case. By the end of half an hour or so of standing in the cold one has got what is practically a more or less dilute raw-beef juice. The jar should now be tightly covered and placed in a saucepan of water, and the latter gradually heated up. The temperature for at least the first hour should be kept below the coagulating-point (167° F.), and from time to time the mixture should be stirred with a fork, and the lumps of meat squeezed against the sides of the jar. During this time any remaining soluble protein is dissolved out. At the end of the hour the tea must be cooked—*i.e.*, its raw appearance and taste taken away by heating it to above the point at which the red colouring matter is coagulated. The simplest plan is to bring it to the boil, and then to remove it from the fire immediately. Prolonged boiling must be avoided, ^{as} tending to render the coagulated protein hard and indigestible. The tea should then be poured off from the residue of beef, not strained, the lumps of beef being held back by a fork.¹ When this has been done, the residue should be squeezed very hard with the back of a spoon in a coarse strainer or sieve, and the juice which comes out added to the tea. The latter may then be set aside to cool. When cold, it will be found to have settled into two layers: a lower layer composed of flocculent particles, and an upper layer of brown fluid. The fat on the top should be removed with a heated spoon.

The reader's particular attention must now be directed to the two layers in the beef-tea. The lower, flocculent one consists of the

¹ The nutritive value of the preparation can be immensely increased by grating down the residue of the meat into fine particles and adding these to the tea. This, however, is not always permissible.

nutritive part of the preparation—namely, the protein. It has been coagulated, of course, by bringing the tea to the boiling-point, but the coagulation has occurred in the form of very fine light particles. Had the tea been passed through a fine strainer or through muslin, as is sometimes recommended, these particles would have been kept back, and the value of the tea proportionately lessened. The upper, or fluid, layer corresponds to what is the whole tea when the latter is imperfectly prepared; in other words, it consists of a solution of the extractives and salts of the meat.

I have found by repeated experiment that 1 pound of lean beef extracted in the above manner with a pint of water yields 28 ounces of good beef-tea, containing $1\frac{1}{2}$ per cent. of protein, and about the same quantity of extractives. Given these facts as to the composition of good beef-tea, what is one to say of its nutritive value? The reply is obvious. Seeing that the preparation, even when carefully made, contains only about $1\frac{1}{2}$ to $1\frac{3}{4}$ per cent. of protein, it can never be regarded as an important aid in the feeding of the sick. If one swallows a pint of it in a day, he has only consumed about one-ninth of the total amount of protein required by a sick person. Of course, beef-tea may be given with some advantage to patients who are confined to an entirely fluid diet, provided the remaining eight-ninths of the protein required are made up in some other form, such as milk or white of egg.

The beef-tea is a pleasant change. It seems to promote appetite to some extent, and its extractives possess, as we have seen, a refreshing influence. It may be objected to beef-tea as a food in comparison with raw-beef juice, that its protein is present in a coagulated condition, and so is more difficult of digestion than the uncoagulated protein of raw-beef juice. I question, however, whether this objection is of any value. Coagulated protein is only difficult of digestion when present in comparatively large masses. Now, in beef-tea the protein forms very fine flakes, which offer a large surface to the digestive juices, and so are very easily dissolved, and I should think that they offer no appreciable opposition to solution by the gastric juice.

It is sometimes claimed for beef-tea that the salts which it contains are of value, as serving to replace those which are excreted from the body in large quantities in some diseases, notably in fevers. It must be questioned whether such a claim has any real value. The salts of the body are in a different position to the other ingredients which help to build it up. When they have served their purpose, and the tissue into whose composition they entered is entirely broken down,

there is no need for the salts to be excreted. On the contrary, they can be retained in the body, and used over again to build up new tissue. The kidney forms, as it were, a kind of turnstile, through which all the soluble constituents of the body must pass on their way out, and if there is a demand for salts in the body, the kidney can refuse to allow these to escape. There is, therefore, no need to pass in new salts by the entrance to the body when the old ones can be turned back at the exit. In other words, there is no justification for the supply of saline-containing beverages in fever.¹

The extractives of meat are, as we have previously seen, excreted entirely by means of the kidneys. If these organs be acutely inflamed, it is of importance to diminish their work as much as possible, and for that reason beef-tea and beef-extracts should always be forbidden to patients who are suffering from acute renal disease.

There can be no doubt that mistaken ideas as to the nutritive value of beef-tea are still very prevalent, especially among the laity, in spite of all that has been written on the subject. Fothergill, in language which is perhaps somewhat exaggerated, says on this subject: 'All the bloodshed caused by the warlike ambition of Napoleon is as nothing compared to the myriads of persons who have sunk into their graves from a misplaced confidence in the food value of beef-tea.' Jessop² calculated that 5·2 tons of beef are used in Metropolitan charitable institutions for making beef-tea every week, and that of this two-thirds are really wasted.

Much of this waste can be prevented by adding to the beef-tea the exhausted fibre of the meat, care being first taken to reduce it to a state of fine division. This is what King Chambers called **whole beef-tea**. Jessop recommends that it should be prepared in hospitals as follows: 25 pounds of beef are boiled with 100 pints of water for three hours, then mashed up, and passed through a colander to reduce it to a fine powder. We thus get meat 'in suspension,' and 3 to 4 ounces of it can be given every three or four hours, making 1½ pints in the day, which is ample.

One can also increase the nutritive value of beef-tea by adding to it baked flour or one of the patent cereal foods, or by stirring in a little somatose, nutrose, aleuronat, etc. The beef-tea then plays the part of a vehicle, and at the same time aids the digestion of the food added to it.

Beef-tea is now prepared on a large scale by various manufacturers as a substitute for the domestic article to be used in hospitals and

¹ For a possible use of the salts of beef-tea in promoting osmosis, see p. 289.

² *Brit. Med. Journ.*, 1889, ii, 462.

other institutions. Some of these preparations compare very favourably with ordinary beef-tea, and are decidedly more economical to use. The following is the composition of some of them :

	<i>Fibrous Beef-tea</i> (<i>Brand's</i>).	<i>Strong Beef-tea</i> (<i>Mason's</i>).	<i>Vril Albuminous Beef-tea</i> (<i>Bovril Co.</i>).
Water ..	83.21	89.02	84.00
Extractives ..	4.52	2.47	4.17
Protein ..	11.40	6.86	10.17
Mineral matter	0.86	1.65	1.66

BEEF-POWDERS.

Ordinary meat contains, as we have seen, 75 per cent. of water, and only 25 per cent. of solids. Any successful attempt to obtain the nutritive matter of meat in a small bulk must therefore be based upon the removal of part at least of the water which it contains. Now, if all the water were removed, the composition of the resulting product would be about as follows :

Protein and albuminoids ..	..	..	..	86.8 per cent.
Extractives ..	..	..	..	7.8 "
Mineral matter ..	..	..	..	5.4 "

That is to say, it would contain 86.8 per cent. of nutriment. Beef-powders have actually been prepared in this way by simply drying the meat. Of these, **Pemmican** is an example, the nutritive value of which has been further raised by the incorporation of 40 parts of fat with every 50 parts of powdered meat,¹ with the result that it is, bulk for bulk, about the most nourishing food known. A man doing hard work—*e.g.*, a Canadian hunter—can eat 2 pounds of it a day, and obtains in that way 222 grammes of protein and 445 of fat.²

Mosquera Beef-meal³ is a powder of beef which has been partially digested by the aid of the ferment contained in pineapple-juice, which has the advantage of not producing bitter by-products. An analysis of it by Chittenden shows that it contains 90 per cent. of nutritive matter, of which fat makes up 13 per cent. and protein 77 per cent., 29 parts of the latter being in the form of albumoses and peptone. It is therefore a preparation of high nutritive value.

Somatose is a completely digested meat-powder, which will be described later (p. 557).

The objection commonly urged against meat-powders, that they

¹ Voit, *Zeit f. Biologie*, 1889, xxv. 232.

² Charque is a similar preparation manufactured in various parts of South America.

³ Supplied by Parke, Davis and Co.

are difficult of digestion, would appear to be unfounded. Dujardin Beaumetz had a large experience of their use, and strongly recommends them as not only readily digested, but also easily administered. He says that boiled beef can be easily dried on a water-bath and ground up in a coffee-mill, and makes an excellent meat-powder. It is most conveniently administered when stirred up in some fluid food, such as chocolate or milk. He found such powders very convenient in forced feeding, as they can readily be given in a semi-fluid form through a nose-tube.

Before closing this chapter, it may be well to summarize some of the conclusions at which we have arrived :

1. The extractives of meat are incapable either of building up tissues or of supplying the body with energy, and are therefore not foods. On the other hand, there is some reason to believe that they promote nutrition indirectly, and bring about a better utilization of the foods with which they are given. It is possible that they act in much the same way as vitamins (p. 18).

2. They do not act as cardiac stimulants.

3. They may possibly help to remove fatigue either by acting on the nervous system or on the muscles directly, but this action cannot yet be regarded as proved.

4. On the other hand, there is no doubt that they powerfully aid digestion by calling out a flow of gastric juice, whilst their pleasant flavour enables them to rouse the appetite. They are therefore useful additions to other foods, especially where the appetite and digestion are feeble, and may also be taken with advantage at the beginning of a meal, as in the form of soups.

5. If taken in large amount they excite diarrhoea.

6. Ordinary beef-extracts (*e.g.*, Liebig's) possess no properties other than those of the extractives of meat. The amount of protein which they contain is negligible.

7. Preparations, such as Bovril and Oxo, to which meat fibre has been added, may theoretically be regarded as foods, but contain far too little protein to admit of their ever being able to contribute appreciably to nutrition.

8. Beef-juices differ from beef-extracts in containing the proteins of meat in a coagulable form. None of them, however, can be taken in sufficiently large quantity to supply much protein to the body.

9. Natural (home-made) raw-beef juice contains about 5 per cent. of coagulable protein, which is as much as many of the patent preparations, whilst its comparative poverty in extractives and

salts enables it to be consumed in fairly large amounts. It is also very much cheaper than the patent preparations.

10. A solution of egg-white flavoured with meat-extract makes a cheap and efficient substitute for beef juices.

11. Ordinary beef-tea, even when carefully prepared, does not contain more than 2 per cent. of nutritive matters. It may aid appetite and digestion, but is of very little value as a food. Its nutritive qualities, however, can be greatly enhanced by adding to it the finely-powdered fibre of the meat ('whole beef-tea'). It is doubtful if the salts of beef-tea are of any real use.

12. The only means of getting the full nutritive value of meat in small bulk is by the use of meat-powders. The alleged indigestibility of such preparations is an error, and they may frequently be turned to good account in feeding the sick.

CHAPTER VII

MILK

In the present chapter cow's milk alone will be dealt with. We shall reserve till later the study of human milk and the milk of some other animals.

I. CHEMICAL COMPOSITION.

As regards its chemical composition, milk occupies an almost unique position among animal foods, for it contains in itself representatives of all three nutritive constituents, proteins, carbohydrates, and fat. This peculiarity it shares, oddly enough, with oysters.

The *proteins* of milk constitute only about 3 per cent. of its total weight. The higher estimates which used to be current are now known to have been based on erroneous analyses. The principal protein is the substance called **casein**, which is kept in a state of more or less perfect solution by its partnership with phosphate of lime. The solution is not clear, but opalescent, and is the chief cause of the opaque whiteness of milk.

Chemists have still much to learn about casein, but enough is already known of its peculiarities to give it a unique place among proteins. To some of these peculiarities allusion will be made immediately, while the consideration of others may conveniently be deferred until we come to the study of human milk.

The other protein of milk is an albumin (lactalbumin), which is present in very much smaller quantity than casein, making up only about one-seventh of the total protein of cow's milk. In human milk it is relatively much more abundant.

The *carbohydrate* constituent of milk is **milk-sugar**, or lactose, which is present to the extent of from 4 to 5 per cent. It differs very much from cane-sugar, and in nothing more than in its comparative freedom from sweetness. In a substance which serves as a food rather than a condiment, this property is a valuable one. Were it not so, milk would pall upon the taste much more readily than it does. Another peculiarity of lactose is that it is hardly capable of being

fermented by yeasts. As a consequence, it is better borne than other kinds of sugar in cases of advanced dilatation of the stomach accompanied by fermentation. On the other hand, it is readily split up by certain micro-organisms, with the production of lactic acid, a process which occurs in the souring of milk, and sometimes also in the intestine, producing diarrhoea. Many cases of infantile summer diarrhoea are brought about in this way.

The fat of milk stands intermediate in amount between the protein and sugar, constituting about $3\frac{1}{2}$ to 4 per cent. of the total weight. It is interesting to note that the amount varies considerably with the needs of the animal for which the milk is designed. In the milk of animals which inhabit cold latitudes the percentage of fat may be very much higher than in that of the cow. Whale's milk, for example, contains 43 per cent.¹ The meaning of this adaptation is clear when one remembers the value of fat as a body fuel.

Fat exists in milk in the form of an emulsion of extraordinary perfection. It has been calculated that in a drop of milk not larger than a pin's head there are 1,500,000 separate fat globules (Rothschild). It will be evident that fat so finely divided as this must be particularly easy of digestion.

When milk is allowed to stand, the fat globules run together, and float to the surface as cream. If this be removed, **skim milk** is left; but when so prepared it still contains some fat, perhaps as much as 1 per cent. If the cream be removed by means of a centrifugal separator, its abstraction is much more complete; for separated milk usually contains less than $\frac{1}{3}$ per cent. of fat. Milk so prepared should be described as 'separated milk.'

Some fuller chemical details about milk fat will be mentioned when we come to butter.

Mineral matter is fairly abundant in milk, forming about 0.7 per cent. Seeing that milk is the sole food of young animals, one is not surprised to learn that its different mineral ingredients are present in exactly the same proportions as in the body of the particular animal which the milk is designed to feed. Now, the chief tissues which a young animal has to build up are muscle and bone. For the former phosphate of potash, and for the latter phosphate of lime, is required, and both of these salts milk contains in abundance. To the rule that the mineral ingredients of milk correspond proportionately to those in the body of a young animal there is one apparent exception. **Iron** is an essential element in the body, and especially in the blood; but iron is very scantily represented in milk. Stockman² calculates that

¹ Frankland, *Chemical News*, 1890, lxi. 63.

² *Journ. of Physiol.*, 1895, xviii. 484.

5 pints of milk would be required to supply the amount of iron necessary for a full-grown man every day. To the young animal, however, this scarcity of iron in milk is a matter of little moment, for it enters the world with a large amount of iron already stored up in its body, which it has obtained from the blood of its mother. In the adult, on the other hand, the lack of iron means a deficiency in the supply required to keep the blood in proper condition; and for this reason persons who are kept for a long time on a purely milk diet are apt to become anæmic.

There remains one other substance which, for the sake of convenience, may be considered under the mineral ingredients of milk. I refer to **citric acid**. It is rather astonishing to find this substance in milk at all, and yet it is present in no inconsiderable amount; for it has been calculated that a good cow yields as much citric acid in the day as would be contained in two or three lemons.¹

As found in milk, citric acid is chiefly combined with lime, as citrate of calcium. This is a gritty substance, only imperfectly soluble, and devoid of any sour taste. The solid particles sometimes met with in condensed milk consist chiefly of it. The possible significance of the presence of citric acid in milk will be pointed out when we come to the subject of infant feeding.

Last, but not least, amongst the constituents of milk is **water**. It forms by far the largest proportion of the milk (87 to 88 per cent.), and holds the other ingredients in more or less complete solution. It is owing to this large amount of water that milk in its ordinary state must be regarded as a dilute and bulky form of food.

One may now sum up what has been stated about the chemical composition of milk in the following table:

Composition of Cow's Milk.

Water	..	87	to 88	per cent.	Fat	..	..	3½	to 4½	per cent
Protein	..	3	..	3½	..	Mineral matters	..	0·7	..	..
Sugar	..	4	..	5	..					

Van Slyke² gives the average of 5,500 analyses of milk made in America as follows:

Water	..	..	87·10	per cent.	Fat	..	..	3·90	per cent.
Solids	..	..	12·90	..	Sugar	..	..	5·10	..
Casein	..	..	2·50	..	Mineral matters	..	..	0·70	..
Albumin	..	..	0·70	..					

These figures merely represent the average composition of a sample of good milk. They are not to be understood to apply to every

¹ Henkel, *Münch. Med. Woch.*, 1888, xxxv. 328.

² *New York Med. Journ.*, 1907, lxxxv. 979.

specimen of milk one may encounter, for there is no food which varies more in composition than milk. Here is what two analytical writers have to say on this point :

'Milk,' says one,¹ 'forms in many cases the entire diet of children and invalids, and under the present conditions it varies so enormously that a doctor, in prescribing so much milk per day, does not know within 30 per cent. how much nourishment he is giving.'

'Excepting meats,' says the other,² 'there is probably no one article of food which is liable to so wide a variation in its percentage composition as the milk supplied to the consumer. The variations are so great, in fact, as to make it entirely possible that one man may pay nearly twice as much as his neighbour for the same amount of nutrients when both buy it at the same price per quart.'

To some extent these variations in composition are unavoidable, depending as they do on the breed and age of cow from which the milk is obtained, on the way in which the cows are fed, and on the period which has elapsed since calving.

In the mixed milk obtained from a large number of cows these variations must to a considerable extent neutralize one another. Hence it is that the total milk from one dairy varies less in composition than that from any one cow in it, and the popular prejudice in favour of feeding an infant on milk 'from one cow' thus rests on a false basis.

On all grounds, both commercial and dietetic, it would be well to have some standard by which to judge of the quality of the milk we buy, and by which to regulate the price we should pay for it. Seeing that it is the solids of the milk that we want, and not its water, and seeing also that the specific gravity of a fluid depends on the amount and nature of the solids dissolved in it, it might naturally be supposed that the specific gravity of a sample of milk would be a guide to the amount of solids which it contains, and consequently to its nutritive value and the proper price to pay for it. This would be quite true were it not that fat is one of the most important solids of milk. Now, fat is lighter than water, for which reason the cream rises to the top. A specimen of milk *plus* its cream has thus an actually lower specific gravity than one from which the cream has been removed (skim milk). The artful milk-vendor has not been slow to find this out, and accordingly he skims his milk, and then

¹ 'The Analysis of Food and Drugs' (Pearmain and Moor), 1897. Part I., 'Milk,' p. 12.

² 'The Use of Milk as Food,' United States Department of Agriculture, Farmers' Bulletin, No. 363.

lowers the specific gravity again to its original point by the addition of water. Thus he effects a double adulteration, and yet leaves the specific gravity as it was; consequently the specific gravity of milk is of no use as a guide to its composition.

In the fat of milk, however, we find a trustworthy gauge of its quality. Fat is not only in itself one of the most important nutritive ingredients of the milk, but a milk which is rich in cream is also rich in protein and sugar, and a 'thin' milk which contains little cream is always poor in the other constituents as well. Commercially, too, there is good reason for accepting the amount of fat as the standard of price, for the fat of milk is its most expensive constituent. The last point in favour of the fat standard is the practical consideration that the amount of fat is more easily estimated than that of any other ingredient of the milk.

What proportion of fat, then, should be insisted upon? On this point, unfortunately, some difference of opinion exists. Analysis has clearly shown that an average sample of good milk contains at least $3\frac{1}{2}$ per cent. of fat. The Society of Public Analysts allows a very liberal margin for fluctuation in individual samples, and regards a specimen of milk with less than 3 per cent. of fat as adulterated. The Inland Revenue Department is even more lenient, and takes $2\frac{3}{4}$ per cent. as its standard. It is to be hoped that the time is not far off when the public authorities will insist upon a uniform standard.¹

From what has been said of the chemical composition of milk, it might naturally be regarded as a fluid form of food, and indeed it is often one of the chief elements in a so-called 'fluid' diet. Strictly speaking, however, milk is not a fluid food. It is only a fluid outside the body. So soon as milk enters the stomach it undergoes a change by which it very soon becomes solid. It is then said to be coagulated or clotted. This coagulation is due to a change brought about in the casein by the ferment called 'rennin.' The exact nature of the change which the casein undergoes is still obscure, but it seems to be split up by the rennin and then to become solid; but this last stage only occurs if salts of lime are present in the solution.

The coagulation of milk is what occurs in the making of junket.

¹ The Departmental Committee on Milk and Cream appointed by the Board of Agriculture in January, 1900, which reported in January, 1901, regards 3.25 per cent. as the minimum amount of fat which genuine milk may contain. Although milk as poor as this may sometimes be produced by cows that are unsuitably fed or in bad health, such a figure seems too low to fix as a standard of purity. The consumer has a right to expect a much richer fluid when he buys milk.

In that process, rennet (a preparation of the ferment rennin) is added to the milk, which is then set aside in a warm place until it is solid. At first the milk forms a jelly, but by-and-by the curd shrinks and a yellowish fluid is squeezed out of it, which is the 'whey.' The rennet which is used in this operation is derived from the lining membrane of the stomach of the calf, but exactly the same ferment is present in the human stomach, and it is important to remember that all raw milk is converted in the stomach into junket very shortly after it has been swallowed. We shall return in greater detail to this subject when we come to the digestion of milk.

At present it may be pointed out that the curd of milk consists primarily of the casein, and of it alone. In process of setting, however, the casein entangles the fat of the milk in its meshes, so that junket consists of the casein along with the fat.

It usually also contains some of the sugar of the milk, for the whey is never entirely squeezed out. For this reason junket may have to be avoided by diabetics.

The 'curdling' of milk must be distinguished clearly from the process of 'clotting' just described. When milk 'curdles,' its casein is simply thrown down in the form of a precipitate without undergoing further change. When milk 'clots,' the casein undergoes profound internal alterations, rendering it practically a new substance with new characteristics.¹

Curdling is due to the production of lactic acid in the milk, which turns the casein out of its partnership with lime salts, and the casein, being in itself not soluble, then falls down as a flocculent precipitate.

The production of the lactic acid is due to a splitting up of milk-sugar by the agency of certain organisms (*Bacterium lactis*, or *Bacillus acidi lactici*) always present in the milk, but the growth of which is greatly facilitated by certain external conditions, of which warmth

¹ Many English physiologists apply the name 'caseinogen' to the chief protein of milk, and restrict the term 'casein' to caseinogen which has been altered by coagulation. This nomenclature has the advantage of emphasizing the difference between the products of curdling and clotting above described. Adopting it, one would say that when milk is curdled caseinogen is thrown down in a flocculent form; when milk clots, the caseinogen is converted into casein. Recently, however, and as the result of further investigations into the chemistry of milk, a different nomenclature has come into use. According to this, the casein of normal milk is combined with calcium, the compound being described as 'calcium casein.' Under the influence of rennin this is converted into 'calcium paracasein.' When these compounds are acted upon by small quantities of acids, one gets the casein or paracasein set free, but if larger quantities of acid are present, the lactate, hydrochloride, or other acid compound of casein or paracasein is formed. The addition of lime-water or bicarbonate of soda to milk converts the normal calcium casein into basic calcium casein, which is not acted upon by rennin. (See Southworth, *New York Medical Record*, 1905, lxvii. 321, and Chafin, *Archives of Pediatrics*, 1907, xxiv., 8.)

and certain electrical conditions of the atmosphere appear to be the chief.¹ This is the reason for the readiness with which milk becomes sour in hot and thundery weather.

We have now to speak of the effects of heating upon the composition of milk.

When milk is boiled in an open pan a tough 'skin' forms on the top. This consists to some extent of coagulated lactalbumin, but partly also of dried caseinogen and salts of lime along with entangled fat.²

The boiling of the milk, possibly by the driving off of carbonic acid gas, seems to cause some of the casein to be detached from the lime salts which hold it in solution, and it then becomes entangled with fat and floated to the surface, and is dried by evaporation into the 'skin' with which everyone is familiar.³ If the skin be removed, another straightway appears, and by continuing the process the milk undoubtedly loses some of its nutritive value. The loss is never great, however, for 100 c.c. of milk, if boiled for a quarter of an hour, lose at most only 0.273 gramme of protein.⁴

Other changes observed in milk heated for a long time are that it becomes of a somewhat brownish colour, and altered taste. The change in colour seems to be due in part to a charring of the sugar in the milk, but in part also to more obscure alterations.⁵ The change in taste sets in quite suddenly when a temperature of 70° C. is reached. It can be got rid of to a large extent by allowing the milk to stand for some time, after being boiled, and then straining it.

The casein also seems to undergo some alteration on boiling, for boiled milk coagulates more slowly than raw milk. To this point we shall return later.

By far the most important result of boiling milk is its sterilization. The significance of this cannot be exaggerated. The bacteriology of milk has been the subject of an enormous amount of research in recent years, with the results of which I cannot hope to deal at all adequately here;⁶ but this, at least, one may say, that the accusation

¹ The influence of electrical conditions is denied by many authorities. A brief discussion of the subject will be found in the *Lancet* of July 5, 1902.

² See Harris, 'Chemistry and Coagulation of Milk,' *Journ. of Anat. and Physiol.*, 1894-95, N.S., ix, 188; and Solomin, *Archiv f. Hygiene*, 1897, xxviii, 43.

³ There is still an absence of agreement amongst different experimenters as to the exact way in which the 'skin' is formed. For papers on the subject, see Jamison and Hertz (*Journ. of Physiol.*, 1901, xxvii, 26) and Rettger (*Amer. Journ. of Physiol.*, 1902, vii, 325).

⁴ Solomin, *loc. cit.*

⁵ See *Maly's Jahres-Bericht Thier-Chemie*, 1895, xxv, 210.

⁶ For a useful summary of the subject, see Conn's 'Dairy Bacteriology,' Bulletin 25, United States Department of Agriculture, 1895. For more exhaustive information, see Swithinbank and Newman's 'Bacteriology of Milk' (London: John Murray, 1903).

that milk is a not infrequent cause of disease has been proved up to the hilt.

Milk, as it comes from a healthy and perfectly clean cow, may be regarded as a sterile fluid; not only is it sterile, it seems even to be possessed of feeble germicidal properties. These ideal conditions, however, are difficult—one had almost said impossible—to attain. Disease in cows, especially if stall-fed, either general and constitutional (*e.g.*, tuberculosis) or local and in the udders (*e.g.*, inflammation), occurs very frequently. It is not to be wondered at, therefore, that milk should often contain the germs of these diseases. Dr. Eastes,¹ for example, found in 186 samples of milk obtained from all sources that tubercle bacilli were present in 11, and the organisms of pus in 47, cases.

Far more commonly, however, the milk gets contaminated either by stagnation in the udders of the cow or from the introduction into it of foreign matter after it is withdrawn. These foreign matters are of all sorts, but are chiefly composed of manure. It was once calculated by Dr. Backhaus that the inhabitants of Berlin consume in this way 3 hundredweight of excrementitious matters per diem.² The hands of the dairyman and the water used in washing the cans are other possible sources of infection.

Once arrived in the milk, the germs are able to grow and multiply very rapidly, so that in a short space of time, especially if favoured by warmth, it may be literally swarming with them.

Roughly speaking, the micro-organisms met with in milk may be divided into two classes—(1) those which produce souring, (2) pathogenic bacteria.

The former are probably harmless, unless so abundant as to produce decomposition of the milk in the intestine, when diarrhoea may be set up. Their chief significance lies in the fact that owing to their presence milk cannot be kept for any length of time without turning sour.

The pathogenic bacteria are the bearers of disease. Amongst the diseases which have been proved to be conveyed by milk are diphtheria, typhoid fever, tuberculosis (which has recently attracted an enormous amount of attention), scarlatina and perhaps cholera.

The disease germs are more easily destroyed than those which produce souring. A temperature of 75° C. (167° F.) maintained for a few minutes is enough to kill most of them. If the milk is to be

¹ 'The Pathology of Milk,' *Brit. Med. Journ.*, 1899, ii. 1341.

² See also Conn, *op. cit.*, p. 11.

preserved for a long time, however, this is not sufficient, and the temperature must be raised above the boiling-point (110°C. ; 230°F.), and kept there for some time. This is the process of sterilization. Sterilized milk is now prepared on the large scale by most of the leading dairy companies, and may easily be made at home by the aid of Soxhlet's or Cathcart's apparatus.¹

Sterilization is undoubtedly the most efficient way of dealing with the germs in milk, but it is not without drawbacks. It alters the taste of the milk, destroys 'vitamins' and the fine emulsification of the fat, coagulates the lactalbumin, and renders the casein less easy of digestion.

Efforts have been made to overcome these disadvantages by pasteurization. This consists in keeping the milk at a temperature of 70°C. (158°F.) for twenty minutes or half an hour. Of this method, however, it may be said that, though it kills most of the disease germs, it is not certain to destroy the tubercle bacillus, as well as some bacteria capable of causing diarrhoea, unless it be carried out very carefully and in closed receptacles.² Further, milk so treated will not keep more than three or four days, for the acid-forming bacteria are still present; nor can one even be certain of avoiding alterations in the taste, for that change sets in, as we have seen, just above 70°C.

For ordinary purposes there is little doubt that simply boiling the milk for a few minutes is the simplest and most satisfactory method of procedure. If carried out in a double saucepan, or Aymard's boiler, very little change in taste of the milk results, especially if it be rapidly cooled after removal from the fire, and subsequently strained, as already described.

There is every reason to advocate the habitual application of one or other of these methods to milk before it is consumed as food; and one looks forward to the day when the drinking of raw milk will be considered as barbarous a custom as the eating of raw meat is at present.

Various methods have been introduced for the permanent preservation of milk without the disadvantages of sterilization. In some of these the milk is treated with peroxide of hydrogen. Another process consists in heating the milk to a temperature of 150°F. , after which it is charged with a mixture of oxygen and carbonic

¹ For much practical information on the sterilization of milk, see *Year-Book of Treatment*, 1897, p. 149. Cathcart's apparatus is described in the *Brit. Med. Journ.*, 1896, i. 29. It has the advantages of being cheap and easily cleaned, and can be obtained from Down, St. Thomas's Street, S.E.

² For a fuller discussion of this subject than is possible here, see Swithinbank and Newman, *op. cit.*

acid gas. It is then heated again to a temperature of 150° F., after which, it is stated, the milk will keep good for an indefinite time, and without any alteration of taste.

In what is known as the 'White Cross' method the milk is first passed through a centrifugal separator, which removes the cream and any suspended impurities. The skim milk is then heated to a temperature of 140° F., a current of pure air being passed through it at the same time. After two or three hours it is reduced to one-fifth of its volume. Meantime the cream is also pasteurized, and is then added again to the milk, and the whole rapidly cooled. The final mixture has only one-fourth the bulk of the original milk. It is free from disease germs, will keep for several weeks, and when the necessary three parts of water are added the product cannot be distinguished from good fresh milk.

Milk can also be preserved by the method of desiccation, which consists in passing it in a thin layer between two heated rollers, or spraying it into a current of hot air, in such a way that all the water is immediately evaporated, and a fine powder results, which contains all the original solids of the milk in a perfectly soluble form.¹ There are now several brands of dried milk on the market, and the product has no doubt a great future before it. An analysis of New Zealand dried milk ('Defiance' brand) gave the following result:

Moisture	4.9 per cent.
Proteins	26.2 "
Fat	27.0 "
Milk sugar	36.3 "
Mineral matter	5.6 "

2. DIGESTIBILITY OF MILK.

It might be supposed that milk, being a fluid, would only remain a short time in the stomach, and rapidly pass on into the intestine. But we have seen that milk is only a fluid outside the body; when it enters the stomach it sets into a solid clot, owing to the action

¹ For experiments proving the sterility of dried milk, see Hoffmann, *Arch. f. Hyg.*, 1906, lix. 216. On the other hand, Delépine, in a Report to the Local Government Board (New Series, No. 97) in 1914, found that although the number of bacteria in milk is greatly reduced by drying, the powder is by no means sterile, several saprophytic bacteria—*e.g.*, *B. mesentericus*—and some pathogenic types—*e.g.*, the bacillus of bovine tuberculosis—surviving the process.

upon it of rennin. Now, the gastric juice is an acid fluid, and it is at first sight surprising that *curdling* does not take place rather than clotting. That this does not happen is no doubt to be attributed to the fact that the alkaline salts of the milk neutralize the acid first secreted by the stomach, and give the rennin time to act before the mixture has attained an acid reaction.

Whether this be the correct explanation or not, there can be no doubt of the fact that shortly after milk has been swallowed it is converted into a solid mass.¹

What the use of rennin is in the stomach is very difficult to see. Certainly clotting is not a necessary preliminary to the digestion of milk, for the latter process can be carried on artificially outside the body to its most advanced stages, with the milk remaining fluid all the time. There is also ample provision for the digestion of milk in the intestine, and if it be so prepared that clotting in the stomach cannot take place, its ultimate digestion is in no way interfered with, nor is it found that patients from whom the stomach has been entirely removed for disease have any difficulty in digesting milk. Rennin, in fact, would almost appear to be a superfluous ingredient in the gastric juice, and its presence there is rendered all the more inexplicable by the fact that it occurs also in such situations as the gizzards of fowls, where milk is never found at all.

After the clot of casein has formed in the stomach, it shrinks into a tough and leathery mass, which offers great resistance to the digestive efforts of the organ. Were the milk merely curdled, the case would be quite different; for the particles of precipitated casein are dissolved with comparative ease.² This is one of the reasons why butter-milk and koumiss are often found to be more 'digestible' than ordinary milk.

¹ If an artificial gastric juice containing a small quantity of rennet be allowed to drop slowly into milk at the body temperature, one invariably finds that clotting occurs before curdling. Observations on dogs by Arthus and Pagès (*Mém. de la Soc. de Biologie*, 1891, 9th series, iii., 131), and on the human subject by Beaumont, Uffelmänn and Reichmann, have shown that clotting takes place within a quarter of an hour after the milk has been swallowed.

² The investigations of Van Slyke and Hart (see footnote, p. 115) have thrown a new light on the digestion of casein. Calcium paracasein, which is the clot formed by rennin, forms a flocculent curd, which is not digested by pepsin unless acid be present, but passes almost straight into the intestine. This happens in young infants whose stomachs secrete little or no hydrochloric acid. If acid be present, paracasein is set free, and forms a much denser clot, and is digested by pepsin. If hydrochloric acid be in excess, paracasein hydrochloride is formed, which sets into a still tougher curd, and takes still longer to digest. (See Fowler, 'Infant Feeding,' Oxford Medical Publications, p. 20.)

If, then, we wish to lighten the labours of the stomach in the digestion of milk, we must endeavour so to arrange matters that the milk shall not form a tough and dense clot after it has been swallowed.

Now, it has been found that the density of the clot which milk forms in the stomach depends, on the one hand, upon the amount of casein and lime salts which it contains, and, on the other hand, upon the degree of acidity of the gastric juice. The richer the milk is in casein and soluble salts of lime, and the more acid the gastric juice, the tougher is the clot. On the other hand, by reducing the proportion of these different factors, the clotting of the milk can either be prevented altogether or made to take place in such a way that the clot is not of great toughness and density.

Obviously mere dilution of the milk with water lessens the proportion of lime salts and casein, and will increase its digestibility. **Dilution with lime-water** is probably not more efficacious than dilution with ordinary water,¹ unless it be in virtue of its slight alkalinity. It has been found, however, that the addition of even large quantities of such an alkali as bicarbonate of soda to milk does not prevent clotting in the stomach.

Barley-water is sometimes recommended as a diluent instead of ordinary water. Whilst I find that it has no greater power of *preventing* clotting than ordinary water, it seems to some extent, by its slight degree of viscosity, to prevent the clot from shrinking into a tough mass. This is due to the starch which it contains. Three-quarters per cent. is the best strength of starch in the milk mixture.

Wright² has shown that the coagulation of milk can be prevented by the addition of one-fiftieth of its volume of a 25 per cent. solution of citrate of soda, which acts by converting some of the soluble lime salts into insoluble calcium citrate. Such **citrated milk** is employed with success in the feeding of infants. The presence of the citrate can hardly be detected by the palate, and milk contains such a large excess of lime salts that the removal of part of them is no disadvantage.

'Aeration' of the milk (such as can be effected by the use of the 'Sparklets' process) is another important means of combating density of clotting. Milk so prepared clots rapidly, but the clot

¹ See 'Observations on Milk Coagulation and Digestion,' by F. W. White (Abstract in *Boston Med. and Surg. Journ.*, 1901, cxlv. 13).

² 'On the Possible Advantages of Employing Decalcified Milk in the Feeding of Infants and Invalids,' *Lancet*, 1893, ii. 194.

pointed out, is the fineness of the particles of the precipitated casein, which enables them to be easily dissolved. The table also confirms the popular belief that boiled milk is somewhat more difficult of digestion than raw milk.

The difference, however, is not great, nor are all observers unanimous on the matter. Verhaegen, for instance, finds¹ that 500 c.c. of boiled milk leave the stomach in two and a half hours, and a litre in three and a half hours, and Reichmann² even goes so far as to state that 300 c.c. of boiled milk remain one hour less in the stomach than a similar quantity of raw milk (three hours as compared with four). This result he attributes to the boiled milk forming a less dense clot. It must also be remembered that boiled milk is more concentrated than fresh milk, for if a litre of milk is boiled for fifteen minutes its volume is diminished by a quarter, and the amount of solid matter to be digested is proportionately raised.

It will be obvious from these conflicting results that the relative digestibility of boiled and unboiled milk cannot yet be regarded as finally settled. It is possible that idiosyncrasy plays a considerable part in the process.

One or two other points bearing on the digestibility of milk still remain to be mentioned. They especially affect its use in diseases of the stomach.

In the first place, it must be pointed out that, thanks to its alkaline salts, and to the large proportion of protein which it contains, milk is able to neutralize a very considerable quantity of acid.³ In some diseases of the stomach, such as ulceration, in which it is desirable to diminish the normal acidity of the gastric juice, this property of milk makes it a valuable article of diet. It has also been pointed out by Pawlow⁴ that, in proportion to the amount of nitrogen it contains, milk requires for its digestion a weaker gastric juice than any other food. Hence, the secretory work required of the stomach for its digestion is small, and this is another point in its favour in many diseased conditions of the stomach. The fat which milk contains also seems to exert a restraining influence on the amount of gastric juice secreted. It may be for this reason that skim milk is more easily digested by invalids. Lastly, milk, like soup, and a

¹ 'Physiologie et Pathologie de la Sécrétion Gastrique,' Paris, 1898, p. 11.

² 'Experimentelle Untersuchungen über die Milch Verdauung im menschlichen Magen' (*Zeit. f. Klin. Med.*, 1885, ix. 565).

³ Ten c.c. of cow's milk can neutralize 4 c.c. of decinormal sulphuric acid (Jäger, *Maly's Jahres-Bericht Thier-Chemie*, 1897, xxvii. 271).

⁴ 'Die Arbeit der Verdauungsdrüsen,' p. 189.

few other articles of diet, seems to produce a secretion of gastric juice independently of reflex nervous influences. It is therefore as sure to be digested if poured into the stomach through a tube as if it had been swallowed in the ordinary way. This is by no means true of most foods.

3. ABSORPTION OF MILK.

When it has left the stomach, the milk reaches the intestine, where its digestion is completed by the pancreatic juice. This juice acts very powerfully on milk—more so than the gastric juice. By reason of this provision there is no need to fear that milk will escape digestion, even if it be so prepared that it does not remain in the stomach, but rapidly passes through into the intestine.

The question next arises, Is the digested milk completely absorbed, or does it leave behind any considerable amount of waste residue? This question may be approached by investigating the degree to which the different constituents of milk are absorbed when isolated and given alone. Proceeding in this way, it has been found that the casein of milk is the best absorbed of proteins.

It is absorbed as well as,¹ or even rather better than,² the protein of meat, whilst the fat of milk enters the blood quite as readily as the fat of beef.³ And one may note in passing the interesting fact that the fat of aerated milk is absorbed rather better than that of milk which has not been so treated.⁴ I am not aware of any experiments in which milk-sugar was given by itself, but it is usual to assume that it is completely absorbed.

Considering these facts, one would naturally expect to find that when milk was given as a whole it would be well absorbed. If the different components of it are so completely received into the blood, surely the whole of them given together will enter the blood with equal ease and completeness? But yet it is not so. Milk, when given by itself as the exclusive diet of an adult, is not very well absorbed—worse, indeed, than any other animal food.⁵ Even under favourable conditions, only about 90 per cent. of the available potential energy contained in the milk ever reaches the blood. The rest escapes from the body as unabsorbed waste. Thus, if 2 litres

¹ Salkowski, *Berlin. Klin. Woch.*, 1894, xxxi. 1063.

² Marcuse, *Pflüger's Archiv.*, 1896, lxiv. 223.

³ 'The Use of Milk as Food,' United States Department of Agriculture, *Farmers' Bulletin*, 363, p. 23.

⁴ *Jahres-Bericht über Thier-Chemie*, 1894, xxiv. 46.

⁵ Prausnitz, *Zeit. f. Biologie*, 1889, xxv. 533.

of milk are taken daily, the loss of dry substance amounts to 5·7 to 7·8 per cent. On 3 litres the waste rises to 10·2 to 11·16 per cent. (Rubner). Prausnitz found a loss of 9 per cent. when 3 litres were consumed daily. One gramme of dried milk ought to yield 5·733 Calories. Owing to defective absorption, it only yields in the body 5·067 Calories. The loss affects the proteins and fat about equally, and, in a notable degree, also the mineral constituents and carbohydrates.

These results apply only to the case of adults, and when milk is the sole food. When the milk forms part of a mixed diet it is much better absorbed. Thus, in an average of ten experiments given by Wait, in which milk was the exclusive food, only 92·1 per cent. of the protein and 86·3 per cent. of the carbohydrate were digested; but in five experiments in which the diet consisted of bread and milk the proportion digested rose to 97·1 per cent. of the protein and 98·7 per cent. of the carbohydrates. The large amount of water which milk contains seems to interfere with the action of the intestines when it forms the sole diet.¹

It is an interesting and remarkable fact that milk is much better absorbed by young children than by grown-up persons.² Thus, even up to the age of twelve the loss of nitrogen, when milk is given alone is only 4·4 per cent., as compared with more than 11 per cent. in the adult.³ In the case of babies absorption is even more complete, the difference being to a large extent due to a more complete absorption of the mineral constituents, the reason for which is the greater demand for lime salts in the infant. This reacts favourably on the absorption of the fat of the milk, for unabsorbed lime salts are apt to form insoluble soaps with the fat, and so hinder its absorption.

The comparative absorption of boiled and unboiled milk has been the subject of a good deal of experimental investigation. It was found that dogs⁴ did not absorb the casein of boiled milk quite so well as that of raw milk, but the absorption of fat was the same in the two cases. Another observer,⁵ who experimented on healthy young men, found that the nitrogen and fat of raw milk were better

¹ 'Nutrition Investigations at the University of Tennessee,' United States Department of Agriculture, Bull. 53, p. 43.

² See Rubner and Heuber (*Zeit. f. Biologie*, 1898, xxxvi. 1). Uffelmann (quoted by Marcuse, *Pflüger's Archiv*, 1896, lxiv. 223) and Camerer (*Zeit. f. Biologie*, 1880, xvi. 493).

³ Prausnitz, *Zeit. f. Biologie*, 1889, xxv. 533.

⁴ Raudnitz, *Zeit. f. Physiol. Chem.*, 1890, xiv. 1.

⁵ Vassilieff, quoted by Cautley, 'The Feeding of Infants,' 1897, p. 214.

absorbed than the same ingredients after boiling ; but this conclusion is disputed by a third.¹

It has further been found in the case of infants and calves that 'sterilized milk' which has been kept at or above the boiling-point for more than an hour is absorbed quite as well as milk which has merely been boiled in the usual way.² Taking the whole of the evidence, the conclusion seems to be justified, that just as boiling does not appreciably diminish the digestibility of milk in the stomach, so it does not to any important extent interfere with its absorption in the intestine. One need have no fear, therefore, that the great advantages of boiling are purchased at the cost of any noteworthy diminution of digestibility or absorption.³

Two other points relating to the behaviour of milk in the intestine call for mention. The first is that milk seems to be absorbed with less expenditure of energy—that is to say, with less wear and tear upon the part of the intestine, than any other food.⁴ This no doubt explains in part the great value of milk-diet in many intestinal diseases.

The other point is that milk seems to exercise a restraining influence upon putrefactive processes in the intestine. The explanation of this, whether it is to be attributed to the casein or to the influence of acids produced from the milk-sugar, is still disputed, but of the fact there appears to be no doubt. There is reason to believe that much of the value of milk diet and milk 'cures' in many cases is due to the diminished absorption of putrefactive products from the intestine which these bring about.⁵

4. NUTRITIVE VALUE OF MILK.

It is frequently said that milk is a perfect food. Now, this is a high claim, and can only be justified in the case of any food if it fulfils all of the following conditions :

1. It must contain all the nutritive constituents required by the body: proteins, fats, carbohydrates, mineral matter and water.
2. It must contain these in their proper relative proportions.
3. It must contain the total amount of nourishment required daily in a moderate compass.

¹ Gaschibowsky, *Maly's Jahres-Bericht Thier-Chemie*, 1894, xxiv. 502.

² See Bendix, *Jahrb. f. Kinderheilk.*, 1894, xxxviii. 393 ; Cautley, *op. cit.*, p. 215 ; and Weber, *Bull. de la Soc. Med. Prat. de Paris*, 1892, p. 77.

³ Experiments on young rats (*Journ. of Hygiene*, 1909, ix. 233) showed no diminution in the nutritive value of milk when boiled, or even when evaporated and dried.

⁴ Pawlow, 'Die Arbeit der Verdauungsdrüsen,' p. 189.

⁵ The alterations in the urine of patients on exclusively milk diet pointed out by Weir Mitchell ('Fat and Blood,' p. 114) are also to be explained by a diminution of intestinal putrefaction.

4. The nutritive elements must be capable of easy absorption, and yet leave a certain *bulk* of unabsorbed matter to act as intestinal ballast.

5. It must be obtainable at a moderate cost.

On examining the claims of milk to be regarded as a perfect food, one finds that it only conforms to the first of the conditions above laid down.

It does indeed contain representatives of all the nutritive constituents required by the body, but it does not contain them in proper relative proportion. Relatively it is too rich in protein and fat, and too poor in carbohydrate, to be a perfect food. In order to obtain the requisite 3,000 Calories of energy daily, one would require to consume about 8 pints of milk, and that would contain about 140 grammes of protein, which is considerably more than is necessary. An excess of protein and fat is essential in the case of infants, where the body substance is being added to by growth and where a large supply of fuel is needed, but it is not necessary for adults. Milk, in fact, is a food for babes, not for men.

Further, milk is much too bulky to be a perfect food. For the complete nutrition of a healthy man doing a moderate amount of muscular work about 8 pints of milk would be required daily. That means that a tumblerful of milk must be swallowed every hour of the working day. This is an inconveniently large quantity, and necessitates the burdening of the system with a considerable surplus of water.

In the matter of ballast, also, milk is deficient. It is true that it is by no means completely absorbed, but the residue is not *bulky* enough to supply a sufficient stimulus to peristalsis, and it is well known to be a constipating food.

Lastly, milk is too expensive to be a perfect food. To live on it alone would cost about 1s. 6d. a day. An ordinary mixed diet can be obtained for less than a shilling.

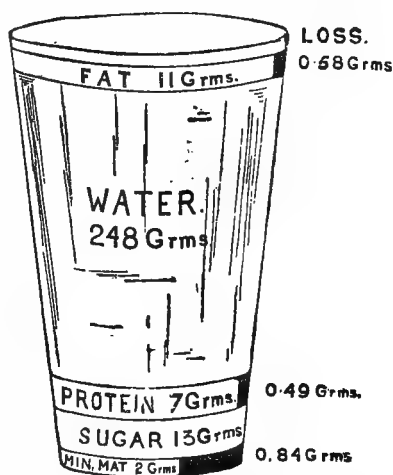


FIG. 8. — ACTUAL COMPOSITION OF A TUMBLERFUL OF ORDINARY MILK, AND PERCENTAGE OF LOSS FROM NON-ABSORPTION.

We conclude, then, that milk is by no means a *perfect* food. On the other hand, it is admirably fitted to supplement the deficiencies of other articles of diet. It is one of the cheapest sources of animal protein. Eight pennyworths of whole milk yield as much protein as ten pennyworths of beef. But milk has the advantage over beef of containing a considerable amount of carbohydrate in addition to its protein and fat, with the result that a quart of good milk is nearly equal in nutritive value to a pound of beef-steak. Skim milk is an even cheaper source from which to supplement any lack of protein in the diet, for it supplies that constituent in a cheaper form than any other animal food except salt fish. Its great value in the dietary of persons to whom economy is of importance cannot be overestimated. It is in carbohydrate that milk is specially deficient. Hence it should be used chiefly in conjunction with other foods rich in that ingredient. Such a food is bread. An interesting practical illustration of the great nutritive and economic value of a combination of skim milk and bread is furnished by the following comparison of a lunch composed solely of these ingredients with an ordinary lunch, such as might be supplied at a restaurant.¹

LUNCH OF SKIM MILK AND BREAD.				RESTAURANT LUNCH.			
In- gredients.	Amount.	Cost.	Fuel Value in Calories.	In- gredients.	Amount.	Cost.	Fuel Value in Calories.
Bread ..	10 oz.	1½d.	755	Soup ..	8 oz.		75
Skim				Beef ..	2 "		275
milk	1 pint	½d.	170	Potatoes	2 "		100
				Turnips	1 "		15
				Bread ..	4 "		300
				Butter	½ "		100
				Coffee :			
				Milk	1 "		20
				Sugar	½ "		55
Totals		2d.	925	Totals		8d	940

It will be observed that bread and milk furnished at a cost of 2d. almost as many Calories (*i.e.*, heat and energy) as were obtained from the restaurant lunch at four times that price.

The claims of skim milk to be regarded as a valuable source of food are thus fully justified, and should be carefully considered by all who are responsible for drawing up an ample and economical dietary for large numbers of persons, such, for example, as the inmates of public institutions.

Unfortunately, the prevailing tendency is to regard milk as a

¹ From 'Milk as Food' (original edition), United States Department of Agriculture, Farmers' Bulletin, 74.

beverage rather than as a food. This is a great mistake, in proof of which one cannot do better than quote an extract from the valuable pamphlet on 'The Use of Milk as Food' issued by the United States Department of Agriculture, to which reference has already been frequently made. The following extract states succinctly the advantages which are obtained from the liberal use of milk in a dietary :

'A very interesting experiment was recently made at the University of Maine, in co-operation with this department, in which the effect of a limited and an unlimited amount of milk was tried at the University boarding-house or "commons." From these studies the following conclusions were drawn : (1) The dietaries in which milk was more abundantly supplied were somewhat less costly than the others, and at the same time were fully as acceptable ; (2) the increased consumption of milk had the effect of materially increasing the proportion of protein in the diet ; (3) the milk actually supplied the place of other food materials, and did not, as many suppose, simply furnish an additional amount of food without diminishing the quantity of other materials ; (4) the results indicate that milk should not be regarded as a luxury, but as an economical article of diet which families of moderate income may freely purchase as a probable means of improving the character of the diet and of cheapening the cost of the supply of animal foods.'

As an article of diet in disease milk occupies a unique position. No single food, it may safely be said, is of so much value. The drawbacks to its exclusive use in health, which it was one's duty to point out above, are now of no account, or are even converted into advantages. The use of milk in the dietary of different diseases will be considered in detail in a subsequent chapter, but some of its general advantages may be mentioned in this place.

Being in a fluid form, it is easily swallowed. This is a great gain in the case of exhausted patients. For the same reason, the quantity given can be very simply regulated and measured. Its fluid form also enables it to be used as a substitute for other beverages, and a glass of milk with each meal is one of the simplest prescriptions for increasing the amount of nourishment a patient is taking. It is often recommended to people who require to be 'fed up.'

The amount of water which it contains causes milk to be a means of quenching thirst as well as of supplying food, and makes it grateful to feverish patients. In virtue of the same property it can act as a diuretic, a function which is of great help in the treatment of some forms of heart disease with œdema, in cases of renal disease, and in all inflammatory affections of the urinary passages.

The bulkiness which its richness in water entails is no serious drawback in most cases of illness. A patient who is at rest and warm in bed requires much less nourishment than an active man, and will often gain weight on 3 or 4 pints of milk a day, although more than twice that quantity is requisite for the needs of health.¹

In addition to this, there is reason to believe that concentrated foods are not well borne in cases of severe disease, and that a moderate degree of dilution is an advantage rather than otherwise. The peculiar behaviour of milk in the stomach and intestine, the fact that it is digested with little secretory effort and absorbed with but a moderate expenditure of energy, and that its presence tends to restrain the development of intestinal putrefaction, have been already referred to, and mark milk out as a food of special value in gastro-intestinal disorders. To these advantages should be added the facts already mentioned, that, though rich in protein, milk is devoid of such 'stimulating' substances as are found in meat, and that its use is attended by a diminution in the excretion of uric acid.

It is probably to a combination of these advantages that 'milk diet' and 'milk cures' owe the benefits obtained from their use.²

From an early age milk was regarded as a sovereign remedy in many diseases. By Hippocrates, Celsus, and Galen it was recommended in phthisis, and especially in gout. Amongst medieval writers Van Swieten and Hoffmann also recognised its great virtues, whilst its most strenuous advocate in modern times has been Dr. Karell, late physician to the Czar of Russia.³ Donkin also did much to make its virtues known, while in later years it has attained prominence as an important part of the 'Weir-Mitchell treatment.'

Karell recommends a trial of the milk cure in dropsies, asthma, neuralgias of intestinal origin, cases of 'malnutrition,' and some diseases of the liver. Its use in diabetes, obesity, and some forms of valvular heart disease will be considered later.

The directions given by those who have had most experience of its use are that the milk should be skimmed, and should be given quite fresh, not boiled. 'A temperature of 212° F., I feel assured,'

¹ See Horton Smith, *Journ. of Physiol.*, 1891, xii. 42, and Prausnitz, *Zeit. f. Biologie*, 1889, xxv. 533; also Weir Mitchell, 'Fat and Blood,' chap. viii.

² It is now believed that some, at least, of the advantages of an exclusive milk diet in disease are to be attributed to a limitation of the intake of salt which such a diet entails. In other words, it is a 'de-chlorinating' diet. (See 'Salt-Free Diet,' p. 556.)

³ 'On the Milk Cure,' *Edin. Med. Journ.*, 1866, xii. 97. An interesting historical résumé of the therapeutic uses of milk will be found in Donkin's 'Diabetes and Bright's Disease,' 1871, chap. i.

says Donkin, 'either seriously impairs or altogether destroys its therapeutic energy, possibly by altering the molecular constitution of the casein or by destroying some vital property with which it is endowed.'

At first not more than 2 to 6 ounces should be given, at regular intervals of three or four hours, none being given at 4 a.m. The milk should be *sipped*, not swallowed at a draught, and may be given either warm or cold as preferred. By the third day the quantity at each feed may be increased to half a pint, so that in all 3 pints are consumed. By the end of a week the total may have risen to 6 pints per day, but one should not attempt to go much above this. The 'cure' should last five or six weeks.

Amongst the 'normal' symptoms exhibited by a patient on a purely milk diet are a certain amount of drowsiness and the passage of a large quantity of urine of a pale greenish colour, which gives no brownish-red ring on the addition of nitric acid. The tongue is covered with a white fur, and there is often a sweetish taste in the mouth. A moderate degree of constipation is a good sign, orange-coloured stools being passed at intervals of two or three days. If this symptom becomes too pronounced, a little coffee or caramel may be added to the morning's milk, or a little stewed fruit may be taken once a day. Diarrhoea is due to the use of a too rich milk.

The objections, frequently of a fanciful nature, which are often urged by the patient at the beginning of such a regimen must be overcome by firmness and tact, while in some cases the addition of a little tea, coffee, caramel, or salt may make the milk more endurable.

CHAPTER VIII

FOODS DERIVED FROM MILK

Whey—Cream—Butter—Butter-milk—Koumiss and Kephir—
Casein preparations.

WHEY.

WE have already learnt that **whey** is the fluid which exudes from clotted milk. It is best prepared by adding to 30 ounces of milk heated to 104° F. two teaspoonfuls of rennet, and setting aside in a warm place till clotting has occurred. The clot must then be broken up very thoroughly by stirring, and the whole strained through muslin. About 22 ounces of whey should be obtained with (approximately) the following composition:

Water	93·64 per cent.	Sugar	4·65 per cent.
Protein	0·82 „	Mineral matter ..	0·65 „
Fat	0·24 „		

Whey can also be made by precipitating the casein by means of an acid—*e.g.*, a sour wine. It is in this fashion that white wine whey is prepared. Alum whey is a similar product. A desiccated whey is made under the name of *Secwa*.¹ It contains all the constituents of whey in a sterile and soluble form, and is a very convenient and useful preparation.

Whey, as its composition indicates, is a fluid of but small nutritive value. It hardly ever enters into an ordinary diet, but is often an aid in the feeding of infants.² It has slight laxative properties, and should be avoided when there is any tendency to diarrhœa.

The so-called **whey cure** is a means of treatment sometimes resorted to in cases of dyspepsia, especially when occurring in gross feeders ('abdominal plethora'). Its range of usefulness is much the same as that of the grape cure, and, as in it, large allowance must be made for the favourable influence of the open air and exercise which form a part of the regimen. The quantity of whey consumed is at first limited to a tumblerful night and morning, but the amount is gradually increased until a maximum is reached of ten tumblerfuls per day. The only other foods allowed are vegetables and fruits.

¹ Casein, Ltd., Battersea, S.W.

² See Ashby, *Edin. Med. Journ.*, 1899, N.S., v. 389.

It should be added that whey is sometimes a useful addition to the diet in cases of nephritis accompanied by constipation and in cases of uric acid gravel. It may also be substituted for milk with advantage when jaundice is present, and in cases of typhoid fever when curds are passed in the stools.

CREAM.

Cream consists essentially of the fat of milk. It would be a mistake, however, to suppose that it consists of that alone. It contains in addition protein and sugar in nearly as high proportion as milk itself.¹ The main difference, indeed, between milk and cream is that in the latter some of the water of the milk has been replaced by fat.

The exact amount of fat in cream varies very much, the differences depending to a large extent on the method by which the cream has been separated. In cream produced by a centrifuge the proportion of fat may amount to 65 per cent., while in ordinary cream, obtained by skimming, it may be merely 20 per cent. or less. The average amount of fat in specimens of centrifugal cream examined by Droop Richmond in 1894 was 48.9 per cent. In 716 samples obtained from the London market in 1889 Vieth found an average of 45½ per cent. for single and 53½ for double cream.²

On an average, perhaps, one may say that a sample of good cream should contain 41 per cent. of fat. There is thus as much, or even greater, need for fixing a legal standard for cream as there is for milk. Some authorities³ would fix the standard at 45 per cent. of fat; others would make it illegal to sell as cream anything which contains less than 25 per cent.⁴

The well-known **Devonshire** or **clotted cream** is a special variety prepared by heating the milk in deep pans, which causes a rapid and very complete separation of the fat. The proportion of fat in such cream is not far short of 60 per cent., as is shown in the following analyses:⁵

Water.		Protein and Sugar.		Fat.		Ash.
1. 32.48	..	8.60	..	58.21	..	0.71
2. 35.54	..	6.80	..	57.09	..	0.57

Devonshire cream contains only about half as much sugar as ordinary cream. For this reason it is peculiarly suited to be a source of fat in the dietary of diabetics.

¹ Cream contains about 2.5 per cent. of protein, 4.5 per cent. of sugar, and 0.5 per cent. of mineral matter.

² *Milchzeitung*, 1889, p. 142.

⁴ Wynter Blyth.

³ Pearmain and Moor.

⁵ Droop Richmond, *Analyst*, 1896, p. 88.

In a physiological sense cream is chiefly to be regarded as a fuel food. It has been calculated that a pint of it should yield about 1,425 Calories, or about as much as $1\frac{1}{8}$ pounds of bread or $1\frac{1}{2}$ dozen bananas or $4\frac{1}{2}$ pounds of potatoes.

In sick-room feeding it is an important aid in getting fat into the diet, for it is very easily digested. Good cream (45 per cent.) contains as much fat as a similar quantity of most cod-liver oil emulsions, and is usually much better borne. A gill of it per day is a not uncommon prescription.

Cream, however, is by no means an economical source of fat. One and a half pints of it do not contain more fat than one pound of butter, and cost about three times as much. Cream, therefore, is to be regarded as a luxury.

BUTTER.

Butter is produced from cream by churning. This causes all the fat globules in the cream to run together into a solid mass, while the fluid part, containing almost all the sugar and most of the casein, remains in the form of butter-milk. The flavour and aroma of butter are due to the growth of organisms in the cream during ripening; butter prepared from pasteurized cream is devoid of flavour.¹

The trace of casein which remains in the butter is of importance, for the decomposition which it undergoes on keeping is apt to make the butter turn rancid. The presence of water in the butter facilitates this change. Butter can be **made to keep indefinitely** by melting it down, and then boiling it till all the water is driven off, as evidenced by the cessation of violent ebullition. The melted butter is then strained through muslin to remove the casein, poured into a bottle, and allowed to cool. If corked up, it will keep almost indefinitely, and when wanted a portion can be removed with a cheese scoop, or the butter can be melted and poured out by standing the bottle in hot water for a short time. This method is largely used in India for the preservation of butter (ghee), and also on the Continent.

The exact amount of fat in butter varies within fairly wide limits, but averages about 82 per cent., or twice as much as the amount in cream. An ounce of butter, therefore, may be reckoned as the equivalent of $\frac{4}{5}$ ounce of pure fat. In addition butter contains 12 to 15 per cent. of water and about 2 per cent. of non-fatty organic matter, chiefly casein and milk-sugar. It is rich also in vitamin.

¹ See Ninth Annual Report of Storrs Agricultural Experiment Station, 1896.

The most striking chemical characteristic of butter fat is its richness in those fatty acids (butyric, caproic, capric, and caprylic) which are soluble in water. Of these it contains about 7 per cent. Butyric acid, indeed, may be said to be the hall-mark of butter, from which it derives its name. Of the insoluble fatty acids present oleic is the most abundant. Butter fat contains 40 per cent of olein. This means that it has a low melting-point ($31-34^{\circ}\text{C.}$), and that in its turn implies, for reasons we have already discussed, that it is easily digested and absorbed. As a matter of fact, butter is the most easily digested of fatty foods. The fat of the human body has also a large proportion of olein, and melts at an even lower temperature than butter (25°C.). The fact that butter fat approximates so closely to it in its proportion of olein may perhaps help to explain the great value of butter as a food.

The ease with which butter is digested renders it of great value as a source of fat in the diet of sickness. In phthisis, diabetes, and many forms of dyspepsia, patients can take $\frac{1}{4}$ pound of it a day without difficulty, and with great advantage to their nutrition. Cooked butter, on the other hand, is much more apt to disagree, probably owing to the liberation of fatty acids in it by the heat employed in cooking. The absorption of butter in the intestine is very complete. Even when $\frac{1}{4}$ pound of it is taken per day, less than .5 per cent. is wasted. This is a more favourable result than would be obtained with any other form of fat, and should teach us that it may be well to give butter a fair trial before having recourse to cod-liver oil or other medicinal fatty preparations.

MARGARINE.

From what has been said as to the chemical composition of butter, it will be apparent that if part of the more solid constituents (stearin and palmitin) could be removed from ordinary animal fats, leaving chiefly olein, the substance left would resemble butter very closely. As a matter of fact, that can be done, and the product is known as *margarine*.¹

Margarine owes its origin to the ingenuity of the French chemist Mège-Mouriès, and was first manufactured under his direction for use in the French Navy in the year 1870. It was originally made by melting down and clarifying various animal fats, that of the ox

¹ Margarine derives its name from 'margarin,' a supposed fat, really a mixture of palmitin and stearin. It is also known as 'oleomargarine,' 'butterine,' and 'Dutch butter,' but by the Act of 1887 all butter substitutes are now described as 'margarine.' In the United States the term 'oleomargarine' is employed. See also Ainsworth Mitchell, 'Edible Oils and Fats' (London: Longmans, 1918).

being chiefly employed ; but at the present day vegetable fats derived from nuts and various seeds and hydrogenated vegetable oils are largely used in its manufacture. The melted fat is allowed to cool slowly, with the result that the stearin solidifies first. The more fluid components (palmitin and olein) are removed by pressure and churned up with a little milk to give them the flavour of butter. The product is then tinted with some vegetable dye, preserved by the addition of a little boric acid, and is ready for use. It has the following composition :¹

Water	..	..	9.3 per cent.	Fat	..	..	82.7 per cent.
Protein	..	..	1.3 "	Ash	..	..	6.7 "

It will be observed that the proportion of fat is exactly the same as in an average specimen of butter, and the only point in which the two differ is that butter has a much higher proportion of the soluble and volatile fatty acids.² There is no reason to believe that this is in any way to the disadvantage of margarine as a food. The fat of our bodies contains no soluble fatty acids, and human milk fat is almost destitute of them too. Indeed, one might almost regard the absence of butyric acid as a point in favour of margarine, for when butter becomes at all rancid butyric acid is liberated from the butyric, and butyric acid is an exceedingly irritating substance. The comparative absence of casein in margarine is also a good point, for casein, as we have seen, tends to promote the decomposition of butter, and its absence should help margarine to keep better.

So much from the chemical side. From a physiological point of view margarine is equally deserving of recommendation. It is absorbed almost as completely as butter, the difference being only about 2 per cent. In other words, 102 pounds of margarine are equal in nutritive value to 100 pounds of butter.³ Whatever may once have been the case, margarine is now made only from pure fats, and the processes to which it is subjected in manufacture insure its further purification. As the flavour of the best variety is equal to that of an average specimen of butter, and as it has the advantage of being very much cheaper, there is every reason to wish that the prejudice against it, which is still rather widespread, should quickly disappear, and that it should be welcomed as an admirable and cheap substitute for a rather expensive, but necessary, food. It has been objected to margarine that it is deficient in 'vitamin,' which is present in butter. There is some force in this in the case of growing children if margarine made entirely from vegetable oils is the sole or main source of fat in their food ; but to adults,

¹ Average of thirty-five analyses by Atwater.

² Butter has 7½ per cent. of butyric ; margarine has only 0.25 per cent.

³ See Röttger, 'Lehrbuch der Nahrungsmittel Chemie,' p. 182.

on a mixed diet, the matter is one of no importance. The further objection that fats of vegetable origin may not play the same part in metabolism as animal fats is purely speculative.

Before leaving the subject of butter, one may consider for a moment what is its relative value as an addition to the diet when compared with jam. This subject is one of very considerable interest to the poorer sections of the community, and involves really two questions: (1) To what extent can sugar (which is the most important ingredient of jam) replace fat in the diet? and, (2) Is the replacement effected at a saving of expense?

The first of these questions has been dealt with to some extent in a previous chapter (p. 26). It need only be repeated here that 1 part of fat is equal to $2\frac{1}{2}$ parts of sugar in fuel value, and that sugar and fat can replace one another to a considerable extent provided these proportions be observed. It would seem, however, although one cannot give any definite scientific reason why it should be so, that fat cannot be wholly replaced in the diet by sugar or other carbohydrate without detriment to health, and that this is especially true of young children.

As regards the second question, it can easily be shown that, even were the substitution of jam for butter justifiable on physiological grounds, it cannot be effected with any real economy. It would require about 3 pounds of jam to be equal in fuel value to 1 pound of butter, and at current prices the former would cost about 1s. 3d., the latter, say, 1s. 2d., a difference slightly in favour of butter.¹ In order, therefore, to effect any saving by substituting jam for butter, one would require to eat less of the former than would really replace the butter, the result of which would be that one's nutrition would suffer. The money saved would be balanced by vigour lost.

The subject is further complicated by the fact that it takes a greater weight of jam than of butter to cover any given piece of bread. I have found that an ordinary slice of bread, when spread the usual thickness, is covered by 40 grammes ($1\frac{3}{8}$ ounces) of jam or by 8 grammes (about $\frac{1}{3}$ ounce) of butter. In other words, as actually used, it takes 5 pounds of jam to go as far as 1 pound of butter; and although it is true that the number of Calories yielded by the former

¹ This calculation is based on the assumption (1) that 1 part of fat is equal in fuel value to $2\frac{1}{2}$ parts of carbohydrate, and (2) that ordinary jam contains about 60 per cent. of sugar (see a paper by Aitchison Robertson, *Scottish Medical and Surgical Journ.*, 1898, iii. 31) and a good sample of butter 82 per cent. of fat. Some physiologists (e.g., C. Voit) assume a different ratio between fat and carbohydrate, namely, that 100 parts of the former are equivalent to 175 of the latter. On this basis, $2\frac{1}{2}$ pounds of jam would be equal in value to 1 pound of butter, and the former would cost 1½d. less than the latter.

quantity is about one-third greater than that obtained from the latter, yet the cost is also considerably greater.

Notwithstanding, then, that the cost of butter and jam is, from a nutritive point of view, almost equal, the housewife will always find the latter more costly than the former, simply because more of it is used. It is true that the extra quantity of jam conveys some extra carbohydrate into the body, but that result could be achieved at less cost by the consumption of a larger amount of bread.

At the same time, it must be admitted that one pays dearly for the pleasant flavour of butter. As far as nourishment is concerned, a pound of dripping is more than the equal of a pound of butter, and only costs half as much.

We have here another example of the fact, already so often pointed out, that in buying foods we pay usually for the likings of the palate rather than for the needs of the body. For those who can afford it, that may be quite justifiable, but for the poor the advantages of margarine and dripping as cheap sources of fat cannot be too strongly insisted upon.

BUTTER-MILK.

Butter-milk is the fluid which is left after the fat has been removed from cream by churning. Its sourness is due to the presence of lactic acid, of which, however, it does not usually contain more than $\frac{1}{4}$ to $\frac{1}{3}$ per cent. Its general composition is shown in the two following analyses:

<i>Protein.</i>			<i>Fat.</i>			<i>Carbohydrate.</i>		
1.	3.0	..	..	0.5	..	..	4.8 ¹	
2.	2.37	..	..	0.4	..	..	3.79 ²	

The chief point in which it differs from milk is its poverty in fat. In this respect it resembles skim milk. The loss of milk-sugar from the formation of lactic acid is too small to be of any significance.

Butter-milk is very easily digested, owing to the absence of fat and to the fact that its casein is present in a finely flocculent form.³

Its nutritive value is considerable, an ordinary glassful yielding about as much nourishment as 2 ounces of bread. It is as a cheap source of protein, however, that butter-milk is chiefly deserving of notice. In respect of this constituent, it is not one whit inferior to ordinary milk, and yet butter-milk is usually thrown out to the pigs. There can be no question that there is here a great waste of a very valuable food. When used in large quantities, butter-milk has diuretic properties which may be a slight disadvantage in health,

¹ Atwater.

² Dunlop, 'Report on Prison Dietaries,' p. 21, 1899.

³ The ease with which butter-milk can be digested has led to its being recommended as a food for infants (see a paper in the *Brit. Med. Journ.*, 1902, ii. 692).

but would rather enhance its value than otherwise in many cases of disease.

KOUMISS AND KEPHIR.

Koumiss is a milk preparation of very considerable antiquity. We find authentic accounts of it in books written early in the thirteenth century, and hints of its existence almost as far back as the dawn of Christianity itself.

Koumiss is fermented mare's milk. **Kephir** is a more modern substitute for it produced from the milk of the cow.

The home of koumiss is in the steppes of European Russia and of Central and South-Western Asia. Its brewers are tribes of nomadic Tartars; its source the milk of the hardy mares of the steppes.

Kephir is, as it were, a spurious koumiss, and was first produced in the Caucasus Mountains from cow's milk fermented with kephir grains.¹

It may be regarded as bearing much the same relation to koumiss that margarine does to butter. It probably has, for all practical purposes, the same nutritive qualities and value as koumiss, but it is not the genuine article, and most likely it would never be used as a substitute were it not for the difficulty of obtaining mare's milk in civilized countries. The fermentation which milk undergoes in the process of conversion into koumiss or kephir is a double one. The sugar of the milk is partly converted into lactic acid by the same process which takes place when milk turns sour; in part also it undergoes the same changes as those by which wine is produced from the sugar contained in the juice of the grape. A 'lactic' and a 'vinous' fermentation both go on. The former begins first, but the latter lasts longest, and the chief anxiety of the koumiss-maker is to promote the growth of the vinous ferment and to restrain that which produces lactic acid.

Now, it is found that mare's milk is a better medium for this double fermentation than is the milk of the cow, and it is so, oddly enough, for those very reasons which make it a poorer food than cow's milk. Mare's milk contains less casein and fat than cow's milk, but is richer than the latter in sugar. Not only so: the sugar

¹ Kephir grains resemble little fragments of cauliflower. Their fermentative power appears to be entirely due to the *Saccharomyces mycoderma*. In addition to this, they contain lactic-acid-producing organisms. The so-called *Bacterium dyspora Caucasica*, which they also contain, does not appear to play any essential rôle in the process, unless, perhaps, it helps to liquefy the precipitated caseinogen (see *Nature*, 1884, xxx. 216; also Rothschild, 'L'Allaitement,' Paris, 1898). For a full account of the history of kephir and the mode of preparing it, see 'Le Képhir,' by W. Podwysotsky (Paris: C. Naud, 1902). This monograph also contains a very full bibliography.

of mare's milk seems to lend itself more readily to lactic acid fermentation than the sugar of cow's milk does. The richness of cow's milk in fat is a positive disadvantage in the process of fermentation, for there is apt to be produced from it small quantities of butyric acid, which is extremely irritating to the stomach, and renders the 'brew' unfit for consumption. So much is this the case, that even if the mares are allowed to pasture on rich grass for but one day the milk of that day becomes unduly rich in fat, and cannot be safely used for the production of koumiss.¹ Hence it is that, if cow's milk is to be fermented—*i.e.*, if one wishes to make kephir—it must first be made to approximate in composition to mare's milk by being skimmed or diluted, or even submitted to both processes.

The chemical changes which take place in the milk under the double fermentation are not difficult to follow. The lactic ferment simply changes part of the sugar into lactic acid. The vinous ferment eats up a very small part of the protein of the milk, and at the same time produces from the sugar a little alcohol and a good deal of carbonic acid gas. The milk thus becomes sour, it effervesces, and is weakly alcoholic. But the lactic acid causes the casein to be precipitated just as it does in the ordinary souring of milk, and the casein falls down in flocculi.

Now, one of the essential points in the making of koumiss is that during the whole process of fermentation the milk should be kept constantly agitated by stirring. This agitation is primarily intended to permit of the access of oxygen to the fermenting fluid, but it has also the result of breaking up the precipitated casein into exceedingly fine particles, and it is to this extremely fine state of division in which the casein is found that much of the ease with which koumiss can be digested is to be attributed. As the process goes on, it would appear² that a small part, at least, of the casein undergoes a sort of spontaneous digestion, and is converted into soluble products.³ One certainly finds that ordinary kephir contains a small amount of peptone.

These changes, of course, only go on gradually, so that at the end of twelve hours of fermentation one gets a 'weak' koumiss which is only slightly sour, and which still looks and tastes quite milky. After twenty-four hours have elapsed some of the casein has been redissolved, with the result that the koumiss is thinner; it has also increased in sourness. This is called 'medium' koumiss. After another twenty-four hours or more most of the sugar has been

¹ Carrick, 'Koumiss,' pp. 45, 54.

² *Ibid.*, p. 41; also *Food and Sanitation*, May 22, 1897.

³ Acid albumin, albumose and peptone (*vide Food and Sanitation*, May 27, 1897).

destroyed, and the 'strong' koumiss which results is a thin, sour fluid which effervesces briskly. In this form it can be kept indefinitely without undergoing much further change.

The net change which has taken place in the original milk may be summed up by saying that the sugar has been to a large extent replaced by lactic acid, alcohol, and carbonic acid gas; the casein has been partly precipitated in a state of very fine division, and partly predigested and dissolved, while the fat and salts have been left much as they were.

That this is an accurate summary of what takes place is borne out by the following analyses:

			Protein per cent.	Sugar per cent.	Fat per cent.	Salts per cent.	Alcohol per cent.	Lactic Acid per cent.
Koumiss ¹ .. ..	..	..	2.2	1.5	2.1	0.9	1.7	0.9
Kephir ² .. ..	..	..	3.1	1.6	2.0	0.8	2.1	0.8
Mare's milk ³ .. ..	..	..	2.6	5.5	2.5	0.5		
Cow's milk ⁴ .. ..	..	..	3.3	4.8	3.6	0.7		
Butter-milk ⁵ .. ..	..	..	3.8	3.3	1.2	0.6	—	0.3

It will be observed from the table that the total protein is hardly less in koumiss and kephir than in mare's and cow's milk respectively. In koumiss the fat is practically the same as that in mare's milk, while the percentage of fat in kephir is naturally lower than that in cow's milk owing to its partial removal before fermentation is begun. The sugar in both milks is very considerably reduced, and is partly replaced by nearly 1 per cent., or sometimes even $1\frac{1}{2}$ per cent., of lactic acid.

The amount of alcohol in both koumiss and kephir is less than 2 per cent. This is not more than the percentage present in many so-called temperance beverages, and is below the standard fixed by the Excise. As a matter of fact, it is impossible to get drunk upon koumiss, no matter how much of it is consumed.⁶ At most only a slight degree of 'hilarity' is produced, followed by sleepiness, but no headache.

Looking at kephir in the light of what we have already learnt as to the digestibility of cow's milk, one will easily perceive that the process of fermentation must render the latter much more easily digested and absorbed than it is in its natural state. The casein—

¹ Rubner, 'Leyden's Handbuch,' p. 93.

² *Ibid.*

³ Wynter Blyth, 'Foods,' 4th edit., p. 258.

⁴ Pearmain and Moor, 'Milk and Milk Products,' p. 4.

⁵ Rubner, 'Leyden's Handbuch,' p. 94.

⁶ Dahl, quoted by Carrick, *loc. cit.*, p. 113.

the great obstacle to the easy digestion of cow's milk—is in such a form that it cannot form masses in the stomach, but is readily attacked by the digestive juices; indeed, it is already partly digested. The carbonic acid stimulates the stomach to a more abundant secretion of gastric juice and promotes the absorption of the fat (see p. 124). The alcohol present co-operates in aiding the process of digestion by causing the blood to flow more briskly through the stomach and intestine, and in addition serves as a food itself. The lactic acid reinforces the digestive action of the acid of the stomach, and may, perhaps, in itself contribute heat and energy to the body.¹

In the matter of **absorption** koumiss and kephir also compare favourably with ordinary milk. May² administered to a patient 6,432 grammes of kephir in two days, containing 724 grammes of solid matter. He found that the percentages of loss in the stools were as follows:

Dry substance	..	..	..	6.4	per cent
Nitrogen	..	..	..	0.4	..
Fat	..	..	..	3.9	..
Ash	..	..	..	34.9	..

The absorption here was evidently better than that of milk, especially as far as nitrogen and fat are concerned.

In the light of these facts one has no difficulty in understanding how it is that enormous quantities of koumiss or kephir can be disposed of in the body without any difficulty. We read, for instance, that the healthy dweller on the steppes is capable of consuming 3 or 4 gallons of koumiss on a hot summer's day, while even the debilitated stomach of the consumptive is equal to disposing of ten large champagne bottlefuls in the twenty-four hours.³

To the enormous quantity of nutriment thus obtained, rather than to any mysterious properties, the undoubtedly high curative value of koumiss in consumption and other wasting diseases is to be attributed. Postnikoff sums up its nutritive qualities in the three words, 'nutrit, roborat, alterat.'⁴ It has also the advantage of possessing diuretic properties and of restraining intestinal putrefaction.

It has been calculated that 4 litres ($3\frac{1}{2}$ quarts) of an average brand of koumiss will contain the following amount of nutritive material:

¹ For experimental proof of the greater digestibility of koumiss than cow's milk, see a paper on Kefir by Dr. Hallion (*Journ. des Practiciens*, p. 402, June 27, 1902).

² *Maly's Jahres-Bericht Thier-Chemie*, 1895, xxv. 454.

³ Carrick, *loc. cit.* See also Dr. Stange on Koumiss Cures (Ziemssen's 'Hand-book of General Therapeutics,' appendix to volume on 'Dietary of the Sick').

⁴ *Food and Sanitation*, May 27, 1897.

Protein	..	..	..	140	grammes	=	600	Calories
Fat	..	..	..	80	,,	=	744	,,
Carbohydrate	..	..	..	140	,,	=	574	,,
							1,918	,,

This is two-thirds of the total amount of Calories required by a man doing moderate work, and contains more than the entire amount of protein he needs daily, and yet $3\frac{1}{2}$ quarts of koumiss can be taken without any difficulty.¹

A glance at the table shows also that kephir is almost identical in composition with genuine koumiss; indeed, being prepared from cow's milk, it is richer in casein, and must therefore be regarded as rather the better preparation of the two, unless for those of very feeble digestive powers. Good kephir is now prepared by most of the large dairy companies, but it is still rather expensive, a large champagne bottleful costing about a shilling. In physiological properties it seems to be identical with the article prepared from mare's milk. The koumiss cure is thus brought to one's own door, and no longer necessitates a journey to the steppes.

In addition to its use in cases of phthisis, koumiss is of value in all conditions of impaired nutrition, in continued fevers, and in convalescence. It may also be used with advantage in chronic catarrh of the stomach or bowels, in cases of hepatic cirrhosis, and in renal disease. It is often better borne in vomiting than any other form of food, and has been recommended in delirium tremens.² It should be given in small quantities at first (not more than a pint in the day) and in small doses, and gradually increased up to the limit of the amount which can be taken without discomfort. Koumiss is an acquired taste; and though many patients object to it at first, they usually come to like it before long.

Soured Milk, which somewhat resembles koumiss in its properties, is dealt with elsewhere (p. 551).

CASEIN PREPARATIONS.

In practical dietetics, the want of a tasteless, compact, easily digested and moderately cheap preparation of pure protein is often felt. Casein is admirably adapted to meet these requirements, and has now been separated from milk and introduced as a dietetic prep-

¹ In the very dry atmosphere of the steppes these enormous quantities of koumiss can be taken, but in the damper climate of England only a more moderate amount can be compassed.

² See 'Cow's Milk Koumiss as a Nutrient in Disease,' by Dr. Brush (*Therap. Gazette*, 1903, xxvii. 443).

aration on its own account. The preparations known as Plasmon, Protene, Casumen, Biogene, etc., are examples of pure casein prepared in various ways. They contain about 80 per cent. of protein.

In these forms casein is digested with ease and absorbed almost in its entirety, and is capable, if necessary, of replacing all other forms of protein in the diet.¹ Added to this, casein presents some special advantages not possessed by other varieties of protein. For one thing, it is readily capable of 'fixing' acids, and so neutralizing them. The power of casein in this respect is three times greater than that of an equal weight of beef.² This property gives it special advantages in those cases of dyspepsia in which too much acid is being poured into the stomach.

Another valuable peculiarity of casein is that it contains phosphorus, which is found also in the products of its digestion, and so enters the blood in an organic form,³ rendering casein a valuable source of that essential constituent of all our tissues. Further, casein contains in itself all the chemical units which are required for the building up of the various body proteins, and can thus cause normal growth even if it is the sole protein present in the diet.

We have also seen that casein is incapable of yielding uric acid by its decomposition, and its use is thus quite admissible in cases of gout.

Lastly, casein is so easily and rapidly absorbed that it has but little opportunity of undergoing putrefaction in the intestine, even if it does not itself, as some have supposed, act as an intestinal antiseptic.⁴

In these forms casein is not clotted by rennet, but it is thrown down from its solution by the addition of acids in rather coarse flakes. It is better, therefore, to administer it mixed with other semi-solid foods, *e.g.*, gruels or thick soup, rather than by itself.

The nutritive value of these preparations is undoubtedly very high, containing as they do fully 80 per cent. of pure protein. An invalid does not require more than 80 grammes of protein daily, and this quantity would be covered by 100 grammes ($3\frac{1}{2}$ ounces) of Plasmon or Casumen. That an amount almost equal to this can be administered daily for prolonged periods has been fully proved by clinical experiment.⁵

¹ Röhmman, *Berlin. Klin. Woch.*, 1895, xxxii. 519.

² Brandenburg, *Deut. Archiv f. Klin. Med.*, 1896, lviii. 71.

³ Salkowski, *Berlin. Klin. Woch.*, 1894, xxxi. 1063, and *Deut. Med. Woch.*, 1896, xxii. 225.

⁴ See Salkowski, *loc. cit.*; Schmitz, *Zeit. f. Physiolog. Chemie*, 1894, xix. 378; and Laquer, *Verhandl. d. Cong. f. Inn. Med.*, 1898, xvi. 546.

⁵ See Oppler, *Therap. Monatshefte*, 1897, xi. 291.

It is as a means of enriching the diet in protein, rather than as sources of energy, that these preparations are specially valuable. Roughly speaking, one may say that one part of them is equal as a source of protein to four parts of meat. Their tastelessness and solubility enables them to be added to other foods, such as soups, milk puddings, cocoa and jellies, raising greatly their nutritive value, and without the patient being aware that any such addition has been made. In many cases of illness, and especially, perhaps, in fevers and diabetes, they increase very considerably our dietetic resources, and have already taken an important place in treatment.

They are far superior to any meat preparation as condensed forms of protein.

Sanatogen¹ consists of casein combined with 5 per cent. of glycerophosphate of sodium. In virtue of its casein it has the same nutritive value as the other preparations considered above. The organic phosphorus which it contains appears to be fully assimilated,² and is believed to exert a tonic effect upon the nervous system. Such an influence is conceivable,³ but is very difficult of proof, and the claims of sanatogen in this respect rest upon a purely empirical basis, although it is only fair to add that numerous clinical observers have testified to the benefits derived from its use.

¹ Sanaphos, Vitafer, etc., are substitutes for Sanatogen.

² Tunncliffe, 'Concerning the Behaviour in the Body of Certain Organic and Inorganic Phosphorus Compounds' (*Archives Internationales de Pharmacodynamie et de Thérapie*, 1906, xvi., fascicule 1 and 2).

³ For a discussion of the rôle of the phosphates in nutrition, see p. 296.

CHAPTER IX

CHEESE, EGGS, AND EGG SUBSTITUTES

CHEESE.

1. *Chemical Composition.*

CHEESE consists essentially of the casein and fat of milk. It is prepared in two ways:

1. The milk may be allowed to clot under the influence of rennet. If pure milk be so treated, the resulting cheese will contain most of the fat—*e.g.*, Cheddar—and the proportion of fat may be rendered still greater by adding cream to the milk—*e.g.*, some forms of Stilton. In other cases part of the cream is first removed by skimming. The cheese will then be proportionately poor in fat—*e.g.*, some Dutch cheeses.

2. The casein may be precipitated by allowing the milk to become sour, or by adding to it an acid, such as vinegar. Under these circumstances the casein carries down with it but little fat, and the cheese produced is a 'lean' cheese—*e.g.*, some Dutch and German cheeses.

The nature of the cheese will also depend on the kind of milk from which it is derived. In by far the majority of cases cow's milk is the source, but Parmesan is made from partly skimmed goat's milk, and Roquefort from the milk of the ewe. In whatever way the casein is obtained, it is next squeezed to remove the whey which is contained in it. If high pressure be employed, the resulting cheese is 'hard,' while a lower degree of pressure produces a 'soft' cheese.

The chief examples of **hard cheese** are these: Parmesan, Gouda, Edam, Chester, Cheddar, Roquefort.

Amongst the **soft cheeses** are the following : Brie, Camembert, Neufchâtel, Gorgonzola, Limburg, Stilton, and Cream.

The soft cheeses do not keep well, and are intended for immediate consumption.

After being submitted to pressure, the next step is to set the mass of casein and fat aside in a cool place to 'ripen.' This process is brought about by the agency of bacteria, and results in chemical changes in the casein which are not as yet perfectly understood. 'Amido bodies,' however, seem always to be produced, and a small amount of peptone. Whether or not the fat in the cheese increases at the expense of the casein is still disputed.

The flavour of the cheese undoubtedly depends on the particular species of germ which has found access to it during the ripening, each species producing definite chemical bodies, which give to that particular kind of cheese its peculiar characteristics. The process seems to be analogous to that which takes place in the manufacture of wines. By the use of different yeasts, one can produce from the same grape-juice wines of entirely different character and bouquet. So with cheese. By the use of different bacteria one should be able to produce from the same casein cheeses of quite dissimilar flavour. No doubt that is what will happen in the future. At present cheese-making is a rule-of-thumb process. By-and-by it will become a science. It has already begun to be so, indeed, in Germany and other countries, and even in some parts of England. The cheese-maker of the future will have a laboratory attached to his factory, in which pure cultures of the bacteria responsible for the flavour of each variety of cheese will be nursed, and instead of 'Stilton' coming from one district, 'Gorgonzola' from another, and 'Gruyère' from a third, all will be produced under one roof. We may look forward then, perhaps, to tasting cheeses hitherto unknown, and to combinations of flavour as yet unsuspected. We may combine the virtues of Stilton with Gorgonzola, or those of Gruyère with Roquefort, for the artist of the palate will have in his hands the precise instruments of science.

Whether this forecast be ever verified or not, there is little doubt that the gross chemistry of cheese will never be much altered. It must always remain, for all practical purposes, a compound consisting essentially of protein and fat. In the accompanying table there is shown the average composition of some of the leading cheeses met with in the market :

COMPOSITION OF CHEESES.¹

Cheese.	Water.	Nitro- genous Matter.	Fat.	Ash.	Average Cost per lb.	Real Cost of 1 lb. of Nutriment
American ..	26·9	32·9	31	4·5	6d.	8½d.
Brie ^a ..	49·7	18·9	26·8	4·5		
Camembert ..	48·6	21·0	21·7	4·4	11 oz., 6d.	8½d.
Cheddar ..	31·9	33·4	26·8	3·9	9½d.	1s. 2d.
Cheshire ..	33·2	29·4	30·7	4·3	9½d.	1s. 2d.
Cream (Full) ..	32·0	28·6	35·9	1·5		
Dutch ..	32·9	30·8	17·8	6·3	7d.	10½d.
Gloucester ..	31·9	36·7	24·7	4·4	9½d.	1s. 2d.
Gorgonzola ..	39·2	25·9	26·9	4·7	9d.	1s. 3d.
Gruyère ..	34·1	31·5	28·2	4·0	10d.	1s. 3d.
Neufchâtel ..	41·0	14·3	43·2	1·4		
Parmesan ..	30·0	43·8	16·5	5·9	11½d.	1s. 4½d.
Roquefort ..	25·1	34·8	31·5	5·5	1s. 1½d.	1s. 6d.
Stilton ..	27·6	23·9	38·9	3·1	1s. 2d.	1s. 7d.
St. Ivel ..	35·9	23·6	35·0	3·7	—	—

Taking the results as a whole, one will not be far wrong in regarding cheese as made up of one-third of water, one-third of nitrogenous matter, and one-third of fat. It is well to remember, however, that there is no inconsiderable amount of mineral matter present as well, consisting chiefly of salts of lime, and that some cheeses at least may contain as much as 2 per cent of milk-sugar.

The 'nitrogenous matter' consists mainly, but by no means entirely, of proteins. Stutzer has estimated the different forms in which nitrogen occurs in Camembert, with the following results:³

Total N	= 2·9 %	N as albumoses and peptones = 0·885 %
N as ammonia	= 0·386 %	„ casein and albumin .. = 0·397 %
„ amides	= 1·117 %	„ indigestible forms .. = 0·115 %

The exact proportions of these different nitrogenous bodies will naturally vary considerably in different cheeses, but it is well to note the large amount of non-protein nitrogen present, which must be allowed for in an estimate of the nutritive value of cheese.

2. Digestibility.

The infiltration of cheese with the fat which it contains must always render it an article of diet not easily dealt with by delicate stomachs, for the fat forms a waterproof coating, which prevents the access of the digestive juices to the casein.

The larger the lumps of cheese which reach the stomach, the slower will this access be. Hence the importance of reducing the

¹ These figures are constructed by taking the averages of the analyses collected by Pearmain and Moor. Prices are those of the Stores.

² König.

³ *Zeit. f. Analyt. Chem.*, 1896, xxxv., p. 493.

cheese to a state of fine division before it is swallowed. This may be done by careful chewing. Now, it is more easy to pulverize a hard morsel than a soft one, for the latter tends always to elude the teeth. For this reason, a piece of hard, dry cheese is more easily digested than a soft and moist piece. A better plan, however, is to break up the cheese before it is eaten. This may be done by grating, but a better way is to dissolve the cheese, and then mix it through some other form of food. An able writer¹ on the chemistry of cookery has pointed out that this may best be done by means of bicarbonate of potash. It was pointed out, when speaking of the chemistry of casein, that it forms soluble compounds with alkalis. Bicarbonate of potash is an alkali, and it seems to combine with the casein of the cheese, and brings the latter into a soluble state. As much bicarbonate of potash as will lie on a threepenny piece is sufficient to dissolve a quarter of a pound of cheese if the latter be first grated or chopped up into fragments. By the addition of milk and eggs, a very savoury and exceedingly nutritious pudding or *fondue* can be prepared, and at a very small cost. It is certainly much to be wished that we should avail ourselves more frequently of such a method of cooking cheese in this country. If cheese is ever to take the place that it ought to have as a cheap and convenient form of protein food, some such method must be employed, for it is the difficulty with which cheese is digested that renders it an impossible food to many persons.²

Another reason, probably, for the disagreeable effects which cheese is apt to produce in the stomach is that in the process of ripening small quantities of fatty acids are produced, and these are always very irritating. The addition of an alkali in the solution of the cheese will neutralize these, and render them less harmful.

It is only in the stomach that the difficulty of digesting cheese occurs; once in the intestine, it is absorbed very thoroughly, over 90 per cent. of the protein being retained in the body, and nearly 90 per cent. of the energy it contains being 'available.'³

3. *Nutritive Value.*

Of the high nutritive value of cheese there can be no doubt. It is just what would be expected when one remembers that a pound of, say, Cheddar cheese represents the total casein and most of the fat in a gallon of milk.

¹ Mattieu Williams. Others, however, have not found that the bicarbonate has any appreciable solvent effect.

² See also 'The Claims of Cheese as a Substitute for Meat,' by Francis T. Bond, M.D. (The Sanitary and Economic Association, Ltd., 21, George Street, Gloucester).

³ U.S. Dept. of Agriculture, Farmers' Bulletin, No. 487.

The average amount of moisture which cheese contains is 33 per cent., the remainder being made up of protein and fat in varying, but on the whole fairly equal, proportions. The amount of water in moderately lean beef is about 73 per cent., the remainder being also made up of protein and fat, the former always largely predominating.

Beef, then, contains less than half as much nourishment as the same weight of cheese. Williams goes further than this, and asserts that a cheese of 20 pounds contains as much nutriment as a sheep's carcass of 60 pounds.

An appeal to the standard of the Calorie gives the same verdict. A pound of cheese yields fully 2,000 Calories of energy, which is more than three times the amount yielded by a pound of moderately lean beef. Furthermore, a pound of cheese can be obtained at about one-sixth of the cost of 3 pounds of beef, which is its nutritive equivalent, and therefore it is at once evident that cheese is a substitute for meat which should be of the greatest value in poor households.

But if cheese is thus to become a cheap substitute for meat, it is of the greatest importance what variety of cheese is bought. For it is true of cheese in an even greater degree than of most other foods, that in buying it we pay for flavour, not for food value. The above table shows the real cost of one pound of nutriment as obtained in the standard brands of cheese. By the real cost is meant what one pound of the protein and fat contained in the cheese would actually cost if all the water were excluded.

The table brings out some interesting points. It shows, for example, that American (Canadian) cheese contains rather more nutriment than the same quantity of Parmesan, and at one-half the price. Stilton, again, costs twice as much as American, and contains about the same proportion of real food. To those who eat cheese simply for the sake of its flavour, and append it as a savoury to the end of an ample meal, these considerations are, of course, of no interest. But to the man who wishes to use cheese as a cheap and efficient substitute for meat one would say, Buy Canadian or Dutch, and preferably the former; for in that way you will be getting much the most nutriment—in other words, much the most muscle and blood and brain—for the money you spend.

EGGS.

An egg is an undeveloped chick. This may sound a truism, but it is the key to the right understanding of the value of eggs as food. For if the chick is developed from the egg without the aid of any external agency save heat, it follows that the egg must contain

within itself all the building material necessary for the making of the chick, along with such a supply of nutriment as the latter requires until it is ready to be hatched. It may be said of eggs, indeed, in the words of Kingsley, that they are veritably

‘Treasure-houses, wherein lie,
Locked by angels’ alchemy,
Milk and hair and blood and bone.’

In chemical language they must contain much protein and mineral matter (especially salts of lime, phosphoric acid, and iron), for these are the only materials out of which ‘blood and bone’ can be built up. They are likely, also, to contain fat, for that is the most compact form in which nutriment for the young chick can be stored. And, as a matter of fact, it is practically of these constituents that an egg consists. Carbohydrate it need not contain, for the chief use of carbohydrate is, as we have seen, to serve as a source of muscular energy; and in the narrow confines of an eggshell muscular movement is impossible.

Passing on to details, it may be said that a hen’s egg of average size weighs about 50 grammes (nearly 2 ounces), the weight being distributed as follows:

Shell	..	..	..	..	..	12 per cent., or	6 grammes
White	..	..	..	..	..	58	29
Yolk	..	..	..	..	..	30	15

The **shell** consists almost entirely of carbonate of lime. As the process of hatching goes on it becomes much thinner by absorption, and one might think that it was used as a storehouse of lime which is drawn upon for the formation of the bones. But apparently this is not so. The egg seems to contain in itself enough lime for the purpose.¹

The **white** consists of a solution of protein shut up in the interior of millions of cells. When white of egg is beaten up, the walls of the cells are ruptured, and the protein escapes. The digestibility of the egg-white is thereby increased, for the walls of the cells offer a slight barrier to the digestion of the protein which they contain.

The protein of white of egg is called ‘egg albumin.’ It would be an error, however, to regard it as a single substance. It seems to consist of a mixture of different proteins, some of which are of a compound nature, and contain a carbohydrate group in their molecule.² This has some bearings on the use of eggs as a food for diabetics, which will be pointed out later.

¹ See Voit in ‘Hermann’s Handbuch,’ Bd. vi., p. 459, footnote.

² There are apparently four different proteins in egg-white—ovalbumin, conalbumin, ovomucin, and ovomucoid. The ovalbumin makes up the greater part of the white. Ovomucin and ovomucoid are glyco-proteins, and are only present in small amounts. See Eichholz, *Journ. of Physiol.*, 1898, xxiii. 163, and *Farmers’ Bulletin*, No. 128, United States Department of Agriculture.

The **yolk** is the storehouse of nutriment for the young chick, and consequently has a very different composition from the white. It contains much less water and more solid matters, amongst the latter being a large proportion of fat. The general composition of the white and yolk is contrasted in the following table (König),¹ and graphically illustrated in the accompanying diagrams (Figs. 9, 10):

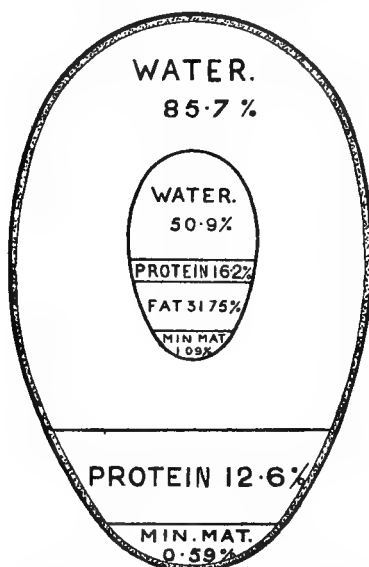


FIG. 9.—PERCENTAGE COMPOSITION OF THE WHITE AND YOLK OF AN EGG.

	Water.	Protein.	Fat.	Other Non-nitrogenous Matter.	Mineral Matter.
White ..	85.7	12.6	0.25	—	0.59
Yolk ..	50.9	16.2	31.75	0.13	1.09

One can see at a glance that the yolk of the egg is relatively its most nourishing part. The complexity of the composition of the yolk is shown by the following more detailed analysis of its constituents :²

¹ For more recent analyses, which, however, do not differ essentially from the above, see a paper by Lebbin on the Nutritive Value of Eggs in the *Therap. Monatshefte*, 1901, xv. 552.

² Goble, quoted by Röttger, 'Lehrbuch der Nahrungsmittel Chemie,' p. 105. See also Juckenack, *Zeit. f. Untersuch. d. Nahrungsmittel*, 1899, xii., p. 905. Malcolm ('Note on the Percentage Composition of Egg-yolk,' *Journ. of Physiol.*, 1901, xxvii., p. 356) has found that the percentages of protein, fat, and phosphorus in the yolks of eggs from the same hen do not vary much, whilst there are considerable differences in eggs from a number of hens even of the same breed. The percentage of lecithin is especially subject to variations. It is probable that a rich reddish yolk contains more iron than one which is of a pale yellow.

1. Water	.. ..	51.8	per cent.
2. Proteins	{ vitellin	15.8	"
	{ nuclein	1.5	"
3. Fats (palmitin, stearin, and olein)	.. ..	20.3	"
4. { Cholesterol	.. ..	0.4	"
	{ Lecithin	7.2	"
	{ Glycerin-phosphoric acid	1.2	"
5. Cerebrin	.. ..	0.3	"
6. Colouring matter	.. ..	0.5	"
7. Mineral matters	.. ..	1.0	"

These different constituents are not merely mixed up in the yolk, but are to a large extent actually combined with one another, producing complex bodies which chemists have not yet entirely succeeded in unravelling.

Of the proteins present, the nuclein alone calls for remark. It is of importance in that it contains phosphorus in organic combination.

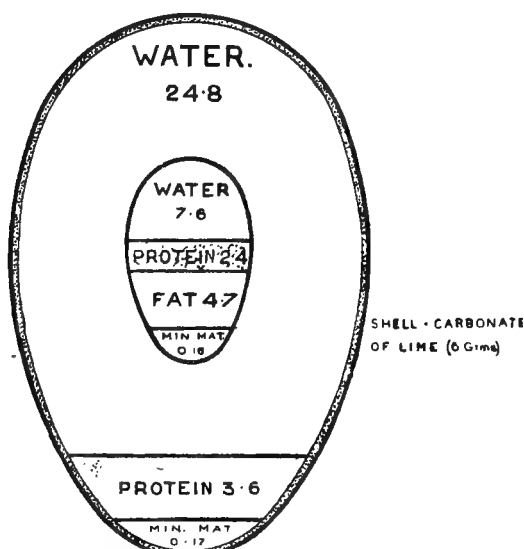


FIG. 10.—ACTUAL COMPOSITION OF AN AVERAGE EGG WEIGHING 50 GRAMMES.

Some of it appears also to be united to iron in a compound to be described immediately.

The third group of constituents—palmitin, stearin, and olein—are simply fats, such as we have already encountered in butter, and have the same nutritive value as these. Their presence in the form of an emulsion in the yolk makes them very easily digested.

In the fourth group are classed together a number of substances

which are of great interest, and give to the yolk of egg much of its peculiar value as a food. They are often included among the fats of the yolk for the reason that, like these, they are dissolved out by ether; and in the table on p. 152, in which the general composition of the yolk is contrasted with that of the white, they are so included. They are, however, very different, chemically, from ordinary fats. They are chiefly characterized by containing a large amount of phosphorus in a form in which it is readily absorbed and appropriated by the body.¹ For this reason these substances are sometimes termed phosphatides.²

Cerebrin is a glucoside found chiefly in nervous tissues. Its nutritive value is unknown.

The most important of the mineral matters are phosphoric acid, lime, and iron. According to König, 100 parts of the ash of the white and yolk of egg have the following composition respectively:

Composition.					Yolk.	White.
Potassium	..	..	..	..	9'29	31'41
Sodium	..	..	..	..	5'87	31'57
Lime	..	..	..	..	13'04	2'78
Magnesium	..	..	..	..	2'13	2'79
Oxide of iron	..	..	..	..	1'65	0'57
Phosphoric acid	..	..	..	..	65'46	4'41
Sulphuric acid	..	..	..	..	—	2'12
Fluorine	..	..	..	..	0'86	1'06
Chlorine	..	..	..	..	1'95	28'82

The phosphorus of the yolk is, as we have seen, almost entirely present as an organic compound. The same is true of the iron, which is probably united with nuclein.³ Now, it appears to be a rule in physiology that mineral matters are most easily absorbed when they form part of an organic compound. Hence, the iron in the yolk of egg easily enters the blood, and it has been found⁴ that dogs fed largely on yolk of egg excrete far more iron in the urine than when they are placed on ordinary diet. One hundred grammes of yolk of egg contain 0'01 gramme of

¹ Hasebroek has shown (*Zeit. f. Physiol. Chemie*, 1888, xii. 148) that lecithin is split up in the intestine into fatty acids, cholin and glycerin-phosphoric acid. The former are saponified and acquire the value of ordinary fats; the cholin is split up into gases, and the glycerin-phosphoric acid is absorbed unchanged. Cholesterol is probably of no nutritive value, but lecithin appears to favour the growth of young animals (*Maly's Jahres-Bericht Thier-Chemie*, 1897, xxvii. 615), and may, perhaps, help in the nutrition of the nervous system. Lecithin derived from the yolk of eggs has now been introduced into medicine in a pure form under the name 'ovo-lecithin.'

² See Thudichum's 'Spirit of Cookery,' p. 589.

³ The compound is sometimes termed a 'hæmatogen,' because from it the colouring matter of the blood of the chick seems to be formed.

⁴ Bunge.

iron,¹ and as the yolk of one egg weighs 15 grammes, it will yield 0·0015 gramme of the metal, or as much as is contained in 18 ounces of milk. Assuming that 10 milligrammes of iron are required by the human body daily (Stockman), seven and a half eggs will suffice for the supply of that important constituent of the blood. Yolk of egg must, therefore, be regarded as a useful food for anæmic persons.

The abundance of calcium in the yolk is very striking. No food contains so much of it except milk. It is probable that most of these lime salts are also present in organic combination, *i.e.*, in a very assimilable form.

The great richness of yolk of egg in fat, in lime salts, and in organic compounds of phosphorus and iron, make it a peculiarly valuable food for young infants, especially those which are suffering from rickets, for it is just those very compounds which a child needs, and a rickety child needs them most of all.

Eggs contain no free purin or purin-yielding substance, and may therefore form part of the purin-free diet which is now so often recommended in gout.

The composition of the whole egg may be summed up as follows:²

Shell	11·2 per cent.
Water	65·5 "
Nitrogenous matter	13·1 "
Fatty matters	9·3 "
Ash	0·9 "

There is no difference in composition between eggs with dark shells and eggs with white shells, and no justification for the popular belief that the former are 'richer' than the latter.³

The composition of the *edible* part (white and yolk together) may be compared with that of meat thus:⁴

	<i>Egg.</i>	<i>Moderately Lean Meat.</i>
Water	73·7	73·0
Protein	14·8	21·0
Fat	10·5	5·5
Ash	1·0	1·0

¹ Socin, *Zeit. f. Physiolog. Chemie*, 1891, xv. 93. Hartung (*Zeit. f. Biologie*, 1902, xliii., p. 195) found that an average egg contains 0·00435 gramme of oxide of iron in 100 grammes of substance (white and yolk together). The yolk is ten times richer in the metal than the white.

² Atwater, 'Composition of American Food Materials,' Bulletin 28, United States Department of Agriculture (revised edition). The percentage of shell is somewhat lower than that given on p. 151.

³ See 'Eggs and their Uses as Food,' by C. F. Langworthy, Farmers' Bulletin, No. 128, United States Department of Agriculture, 1901.

⁴ Atwater, 'Composition of American Food Materials,' Bulletin 28 (average of sixty analyses).

One sees at a glance that eggs contain almost the same total of nutritive matter as meat, but are relatively richer in fat and poorer in protein.

Eggs are thus admirably adapted chemically to supplement a food rich in carbohydrate, moderately rich in protein, but poor in fat. Such a food is found in rice and many cereals, and the addition of eggs to these in the form of puddings makes a complete food. We have here another instance in which ancient experience and practice are justified by modern science.

The composition of a goose's or duck's egg is very similar to that of the hen, but, of course, they are larger. An average duck's egg weighs about $2\frac{1}{2}$ ounces, a goose's egg from $5\frac{1}{2}$ to $6\frac{1}{2}$ ounces.

THE COMPOSITION OF EGGS.¹

	Refuse. Per Cent.	Water. Per Cent.	Protein. Per Cent.	Fat. Per Cent.	Ash. Per Cent.
Hen :					
Whole egg as purchased ..	11.2	65.5	11.9	9.3	0.9
Whole egg, edible portion ..	—	73.7	13.4	10.5	1.0
White	—	86.2	12.3	0.2	0.6
Yolk	—	49.5	15.7	33.3	1.1
Duck :					
Whole egg as purchased ..	13.7	60.8	12.1	12.5	0.8
Whole egg, edible portion ..	—	70.5	13.3	14.5	1.0
White	—	87.0	11.1	0.03	0.8
Yolk	—	45.8	16.8	36.2	1.2
Turkey :					
Whole egg as purchased ..	13.8	63.5	12.2	9.7	0.8
Whole egg, edible portion ..	—	73.7	13.4	11.2	0.9
White	—	86.7	11.5	0.03	0.8
Yolk	—	48.3	17.4	32.9	1.2
Plover :					
Whole egg as purchased ..	9.6	67.3	9.7	10.6	0.9
Whole egg, edible portion ..	—	74.4	10.7	11.7	1.0
Guinea fowl :					
Whole egg as purchased ..	16.9	60.5	11.9	9.9	0.8
Whole egg, edible portion ..	—	72.8	13.5	12.0	0.9
White	—	86.6	11.6	0.03	0.8
Yolk	—	49.7	16.7	31.8	1.2

When kept, eggs gradually lose water by evaporation and become lighter. A fresh egg should sink at once in a 10 per cent. salt solution (about 2 ounces to a pint), but the longer it has been kept the nearer the surface it will float.

When an egg becomes rotten, alkaline sulphides are produced, apparently from the white, and these being acted upon by phosphoric acid derived from the yolk, sulphuretted hydrogen is liberated,

¹ United States Department of Agriculture, Farmers' Bulletin, No. 234.

which gives to a rotten egg its very disagreeable smell. If an egg is boiled for a long time the same effect is produced in a minor degree, and it is well known that an egg so treated is apt to have a slight odour.

The digestibility of eggs in the stomach depends largely upon the form in which they are taken. Some experiments have been made on a healthy man which throw light on this subject.¹ Two eggs were given, cooked in different ways, and portions of the stomach contents were withdrawn at intervals, the time being noted at which any portion of egg ceased to be recovered. The results were as follows:

2 eggs lightly boiled have left the stomach in	..	..	..	1 $\frac{3}{4}$ hours
.. raw have left the stomach in	..	..	..	2 $\frac{1}{4}$ "
.. poached + 5 grammes of butter have left the stomach in	..	..	..	2 $\frac{1}{2}$ "
.. hard boiled have left the stomach in	..	..	..	3 "
.. as an omelette have left the stomach in	..	..	..	3 "

The figures speak for themselves. One or two points, however, call for comment. It is surprising to find that lightly boiled eggs are more quickly disposed of by the stomach than eggs given raw. One must take care, however, not to jump to the conclusion that lightly boiled eggs are more suited to a stomach requiring rest than raw eggs are. As a matter of fact, raw egg seems to be scarcely digested in the stomach at all, but passed on out of it to a large extent unchanged. Some observations bearing upon this point were made on a patient in whom, as the result of disease, an artificial opening had formed into the intestine a very short distance below the point at which it joins the stomach.² It was found that when raw egg was given by the mouth more than half of it ultimately escaped by this opening unchanged. The explanation may perhaps be that raw egg is such a bland fluid that it does not excite the secretion of gastric juice nor the movements of the stomach. Hence it may linger longer in the stomach than an egg which has been lightly boiled, because the solid particles of the latter stimulate both secretion and movement. The raw egg is thus really the less irritating to the stomach of the two, and makes less demand upon it, for its digestion is really performed in the intestine.

The difference in digestibility between hard and soft boiled eggs depends to some extent, also, on the degree to which the former are subdivided. If finely chopped up, they could probably be disposed of as easily as the soft-boiled eggs.³

¹ Penzoldt, *Deut. Arch. f. Klin. Med.*, 1893, li., p. 535.

² Busch, *Virchow's Archiv*, 1858, xiv., p. 140.

³ A great many observations have shown that the white of one egg finely chopped and taken with 2½ ounces of water remains in the stomach for one and a quarter hours (Jaworski and Gluzinski, *Zeit. f. Klin. Med.*, 1886, xi, 84).

I am not acquainted with any experiments on the relative digestibility of the white and yolk of egg, but one would expect the latter, owing to its larger proportion of solids and great richness in fat, to be more slowly dissolved in the stomach than the white.

It must also be pointed out that **idiosyncrasy** plays a large part in the digestion of eggs. Some persons are unable to swallow even a small particle of egg without becoming violently ill, the symptoms ranging from slight urticaria to vomiting, syncope, and coma. Apparently their digestive juices act on the egg in such a way as to produce poisons from it.¹ In other cases sulphuretted hydrogen seems to be produced during the digestion of the egg. As the table on p. 154 shows, the sulphur of the egg is confined almost entirely to the white. That part should, therefore, be specially avoided in such conditions.

The **absorption** of eggs in the intestine seems to be very complete. It has been found that even when 21 hard-boiled eggs are taken daily they are absorbed as completely as meat, only 5 per cent. of the dried substance being lost.²

Eggs, therefore, leave a very small residue in the intestine. This, coupled with the fact that they contain so much lime, may perhaps explain their constipating effect on some persons.

Chemical considerations have shown us that the **nutritive value of eggs** is due almost entirely to protein and fat. One egg contains enough of these to yield 70 Calories of energy. Half a tumblerful of good milk or $1\frac{1}{2}$ ounces of fat meat would yield about as much.

Roughly speaking, 15 to 20 eggs may be taken as the nutritive equivalent of 2 pounds of medium fat meat.

The absence of carbohydrates prevents eggs from being in any sense a complete food, and it would require 20 of them a day to supply even the amount of nitrogen required by a healthy man. They cannot be regarded as a *cheap* source of protein, though the convenient form in which their nutritive constituents are presented, and the readiness with which they lend themselves to the art of the cook, must always render them a most useful form of food. In addition to these considerations, the peculiar chemical composition of the yolk causes that part of the egg to be a valuable source of

¹ For illustrative cases, see *Med. and Surg. Review*, 1899, ii. 299, and *L'Echo Méd. du Nord*, August 13, 1905 (Abstract in *Med. Rev.*, 1905, viii. 586). Also a case described by A. T. Schofield (*Lancet*, 1908, i. 716) in which he succeeded in establishing tolerance.

² Rubner, *Zeit. f. Biologie*, 1879, xv., p. 115. For an account of more recent experiments, which, however, yielded almost identical results with Rubner's, see *Farmers' Bulletin*, No. 128, p. 17, United States Department of Agriculture, and Aufrecht and Simon, *Deut. Med. Woch.*, 1908, xxxiv. 2309.

phosphorus, lime and iron, of which advantage may well be taken in the dietetic treatment of certain diseases, more especially of early life.

There are but few artificial preparations of eggs. Eggo consists of yolks of eggs dried at a low temperature, so that they are capable of being redissolved. It is a convenient form in which to keep eggs for cooking purposes.

Condensed eggs prepared by evaporation *in vacuo*, either with or without the addition of sugar, are also obtainable for a similar purpose.

Custard-powders are sold as 'substitutes' for eggs. The majority of them consist chiefly of starch, to which a yellow colour is imparted by mixture with some vegetable dye—*e.g.*, turmeric. The following analyses of some of them were published in *Food and Sanitation* (November 25, 1893):

	Bird's Custard- powder.	Goodall's Custard- powder.	Goodall's Egg- powder.	Borwick's Egg- powder.	Yeatman's Egg- powder.	'Model' Egg- powder.
Starch	86.25	84.45	51.03	26.38	52.32	53.82
Albuminous com- pounds	0.59	0.58	6.01	2.96	6.00	5.06
Soluble colouring matter	0.88	0.90	—	—	—	—
Baking soda	—	—	15.33	50.70	22.11	26.71
Tartaric acid	—	—	13.69	10.33	11.37	6.19
Phosphates	—	—	0.24	—	—	—
Carbonates of lime and magnesia	—	—	2.70	—	—	—
Chlorides and sulphates	—	—	—	—	—	traces
Water	11.83	13.69	11.0	9.63	8.20	8.22
Ash	0.45	0.38	—	—	—	—
	100.00	100.00	100.00	100.00	100.00	100.00

It is obvious that they have nothing in common with eggs except a yellow colour, and that their nutritive value can be in no way equal to that of a genuine custard.

CHAPTER X

VEGETABLE FOODS

THE foods with which we have been dealing up till now are derived from the animal kingdom. In the present chapter we approach the study of that large and varied class of foods which we obtain from vegetable sources. We may consider in the first place, in a general way, the chemical composition, digestibility and nutritive value of the vegetable foods as a whole, contrasting them in these respects and in their economic aspects with foods of animal origin, and then proceed to the detailed study of the different groups into which vegetable foods may be subdivided.

I. CHEMICAL COMPOSITION OF VEGETABLE FOODS.

From a chemical point of view, the most striking feature of the vegetable foods is the large proportion of carbohydrates which they contain. This peculiarity marks them off at once from the animal foods, for the latter, with a few exceptions, such as milk, contain little or no carbohydrate at all. Richness in protein and fat is the characteristic of animal foods, abundance of sugar and starch that of the products of the vegetable kingdom.

Now, starch is by no means such a concentrated form of carbon as fat is. Indeed, it takes 221 parts of starch to be equal to 100 parts of fat. This is one reason why vegetable foods must be regarded as dilute and bulky, while animal food is concentrated and compact.

But vegetable foods possess not merely abundance of carbohydrates: they contain proteins and fats as well. Some members of the class, such as the pulses, are peculiarly rich in the former; others, such as nuts, in the latter; but of vegetable foods as a whole it may be said that more than the animal foods they contain representatives of all the three groups of nutritive substances. In consider-

ation of this fact, the vegetable kingdom must be pronounced a better source of human food-supply than the animal, and if one were confined in his selection of a dietary exclusively to one kingdom or the other, it would be wiser to patronize the miller and greengrocer rather than the butcher and fishmonger, for it is undoubtedly possible to live on vegetables alone, whereas it is difficult to live for any length of time on nothing but meat. The better way for most people, however, is to avail themselves of the resources of both kingdoms.

It is now necessary that we should consider for a moment in somewhat greater detail the different groups of nutritive substances which enter into the composition of the vegetable foods.

Of the **carbohydrates** we have already mentioned sugar and starch. Sugar is the form in which carbohydrate circulates in plants; starch is the shape in which it is stored up. If a plant has manufactured more carbohydrate than it requires for its present purposes, it puts aside the surplus in the shape of starch, and when the pinch of need comes upon it, and it requires a supply of carbohydrate again to maintain its life, some of this store of starch is changed back into sugar by the help of the ferment diastase, and circulates once more throughout the plant. Sugar, then, is the soluble form of carbohydrate: it is carbohydrate in circulation, and corresponds to the current coin in our pocket; starch is the insoluble form of carbohydrate: it is carbohydrate in reserve, and corresponds to the bullion in the bank. It is important to grasp this mutual convertibility of starch and sugar. We shall see later that a precisely analogous process goes on in the animal body, and that all the starch which we eat must first be converted by digestion into sugar before it can circulate through our bodies and be available as food.

A heap of **starch** is really made up of minute grains, just as a heap of sand is, but the starch grains are much smaller than those of sand, and can only be seen with the aid of a microscope. When so examined, they will be observed to have various shapes, round, oval or polyhedral, depending on the plant from which the starch is derived. They also exhibit concentric markings. These indicate that the starch grain is built up, like a sandwich, of different layers. One set of layers consists of true starch (*amylose* or *granulose*); the other set consists of a form of cellulose, formerly known as starch cellulose or *farinose*. The outer layers of the starch grain are the densest, and the most external one of all seems to consist entirely of starch cellulose.

These little starch grains are not dissolved by cold water. This

is one reason why starch is the form in which plants stow away their surplus carbohydrate; being insoluble, there is no risk of its being all washed away by rain if the plant gets injured. Another reason is that starch is a more concentrated form of carbohydrate than sugar, and packs into a smaller bulk.

If boiling water be poured on the grains, they swell up and burst, and the true starch escapes from between the layers of cellulose, and forms with the water the gelatinous solution familiar to the laundress.

It is this rupture of the starch grains that we seek to bring about by the cookery of vegetable foods, for one can readily imagine that starch grains which have been thus broken up and brought into solution will be much more easily attacked by the digestive juices, and converted into sugar, than when eaten in their raw and unruptured state.

If starch be subjected to dry heat, it undergoes a modification by which it becomes soluble in water, and is ultimately converted (at a temperature of about 300° F.) into the form of carbohydrate known as *dextrin*. This is a gummy substance, and is familiar to everyone as the sticky material on the backs of postage stamps. This change also takes place to some extent in cookery. The crust of a loaf of bread, for example, consists mainly of starch which has been converted by the heat of the oven into soluble starch and dextrin.

We saw that in the case of meat the nutritive ingredients (proteins) were contained in minute tubes held together by a connective tissue which yields gelatin. In the case of most vegetable foods, on the other hand, the chief nutritive ingredient (starch) is contained in a vast number of minute compartments, more or less cubical in shape, and collectively known as 'cells.' The walls of these and the framework which holds all the cells together are composed of a substance known as *cellulose*, the most familiar form of which is paper.

Now, cellulose also belongs to the carbohydrate group, but it is especially characterized by its extraordinary insolubility. Neither cold nor hot water has any effect upon it, and in order seriously to influence it one must boil it with a dilute acid. In its old age cellulose gets infiltrated with resinous matter and becomes wood; it is then past the stage of being much affected, even by acids. The presence of cellulose in nearly all forms of vegetable food is a fact of great practical importance when one considers that it encloses the starch grains in the vegetable cell, much in the same way as a sheet

of brown paper encloses a parcel of oranges, and when one remembers its peculiar insolubility it becomes obvious at once that this wall of cellulose must present a great obstacle to that penetration of the nutritive ingredients by the digestive juices which is of the first importance for the proper carrying out of digestion.

In addition to starch and cellulose, there is another and peculiar group of carbohydrates met with in vegetable foods, the members of which are spoken of by some writers as **pectin bodies**, while others class them together under the general term 'pectose.' These are the substances which give to fruits their power of forming jellies when boiled, and little is known of their exact chemical nature, but they appear to be converted into a special kind of sugar when digested (pentose), which is at least partly assimilable by the body.¹

The last group of carbohydrates which occur in vegetable foods are the **sugars** of which brief mention has already been made. Their importance as foods is such as to merit a more detailed consideration later (see Chap. XV.).

The **nitrogenous substances** met with in vegetable foods may be divided, as in the case of meat, into those which are proteins and those which are not. The vegetable proteins belong mainly to the globulin class. These are easily dissolved by water containing a little salt, and may be lost to an appreciable extent from vegetables which are left soaking in such a mixture. It should be mentioned, also, that vegetable foods contain less of the substances known as nucleo-proteins than one meets with in animal tissues. The practical importance of this will be pointed out when we come to consider the dietetics of gout.

Both varieties of protein, vegetable as well as animal, are coagulated by heat, and both are rendered less digestible thereby. The broad result is that cooking diminishes the digestibility of animal foods, because they are mainly composed of protein, but raises the digestibility of vegetable foods because the latter contain, as a rule, very little protein along with much starch, and cooking, as we have seen, renders starch much more easy of digestion.

¹ Some of these bodies appear to be of the nature of dextrins, whilst others, perhaps, stand nearer to starch. It might be well to restrict the term 'pectins' to the former group: they probably bear the same relation to the pentoses, or sugars with five carbon atoms, that dextrin does to the six-carbon-atom sugar, dextrose. The other group may be spoken of as pentosanes. The sugars to which they give rise are also found in many ripe fruits, and are certainly not easily assimilated by the cells of the body, and are apt to appear in the urine if the fruits containing them are eaten in excess.

Vegetable foods resemble animal foods in containing a large number of nitrogenous substances which are in no sense proteins. None of these, however, corresponds in any way to the 'albuminoids' (e.g., gelatin) met with so abundantly in the animal kingdom.

On the other hand, **extractives** are well represented. Most of these belong to the group of chemical substances called 'amides.' Asparagin, which is richly present in the potato, is one of the best known. Its uses as an ingredient of the food will be considered when we deal with the potato.

Of the **fats** found in vegetable foods little need be said. They resemble in chemical composition the animal fats, but appear to contain, as a rule, more of the oily constituent (olein) and less of the more solid components (stearin and palmitin) than the fat of animals. Hence they tend to have the consistency of oils rather than of solid fats. This, however, increases rather than lessens their digestibility, while their nutritive value seems to be fully equal to that of the more solid animal fats.

The remaining chemical constituents of vegetable foods are *water* and certain *mineral salts*. There is an extraordinary amount of **water** present, much more than one is inclined to fancy. Even green peas and lentils, which are the richest in solid constituents of the commoner vegetable foods, contain 78 per cent. of water, while in green vegetables and most fruits water accounts for more than 90 per cent. of the weight of the fresh food. This means that a cabbage is really a more watery form of food than milk, for the latter only contains 87 per cent. of water. The apparent solidity of green vegetables is deceptive, and is merely due to the framework of cellulose which supports them.

This wateriness of most vegetable foods is one of their most essential properties, and is mainly responsible for the low nutritive value of many of them when compared with the largeness of their bulk. Unfortunately, also, most vegetable foods become even more watery when subjected to the process of cooking; their last state is thus worse than their first, whereas in the case of animal foods the contrary is the case.

Attempts have been made, and with a large amount of success, to **reduce the bulk of vegetable foods** by removing the water which they contain. As early even as the middle of last century a patent was taken out, by a certain Mr. Masson, for effecting this by a process of drying. His method enabled him to put up 70 pounds weight of

cabbage in a tin of 11 pounds. In recent years several processes effecting the same object have been introduced, with the result that one can obtain all the commoner vegetable foods in a remarkably compact form, and yet without the sacrifice of any of their nutritive ingredients or flavour. The conveniences of this in the case of military transport and camping expeditions are obvious.

The **mineral constituents** of vegetable foods are numerous and important. Further reference will be made to them when the different groups of vegetable foods are dealt with separately, but at present one may point out that potash is in most of them more abundantly represented than soda. This has been alleged by a distinguished physiologist (Bunge) as the reason why herbivorous animals have a craving for sodium in the form of common salt (sodium chloride).

A large proportion of the bases amongst the mineral ingredients of vegetable foods are united with organic acids, and these, when burnt up, either outside or inside the body, yield alkaline salts. The excretion of these in the urine causes it to have a less degree of acidity in vegetable than animal feeders, and is, as we shall see, turned to therapeutic account in the case of those who are suffering from stone or gravel.

2. DIGESTIBILITY AND ABSORPTION OF VEGETABLE FOODS.

1. *In the Stomach.*—As a class, vegetable foods are not to any large extent really digested in the stomach, because starch, their chief ingredient, is entirely unaffected by the gastric juice. Hence it follows that it is only those vegetable foods which are particularly rich in protein, such as the pulses, which throw upon the stomach any large share of the *chemical* part of their digestion. On the other hand, the manipulation of bulky vegetable food, its reduction to a state of fine division, and the passing of it on into the intestine, all entail upon the stomach a large amount of mechanical effort. As a consequence of this, animal food, which necessitates for its digestion more chemical but less mechanical work on the part of the stomach, is really better borne by persons of enfeebled digestive power than the majority of vegetable foods are.

2. *In the Intestine.*—It is customary to state that vegetable foods are less completely digested and absorbed in the intestine than

animal foods. Stated in such general terms, the proposition cannot be substantiated. It depends entirely on the form of vegetable food. A glance at the table will show that the foods which are the most completely digested and absorbed of all (white bread, macaroni, and rice) are vegetable foods, while meat and eggs rank distinctly after these.

RELATIVE ABSORPTION OF SOME ANIMAL AND VEGETABLE FOODS.¹

<i>Food.</i>	<i>Dry Substance not Absorbed.</i>	<i>Food.</i>	<i>Dry Substance not Absorbed.</i>
White bread	4 per cent.	Milk	9 per cent.
Macaroni	4 "	Peas	9 "
Rice	4 "	Potatoes	11 "
Meat	4½ "	Black bread	15 "
Eggs	4½ "	Cabbage	15 "
Maize	7 "	Turnips	20 "

Two factors appear to determine the digestibility of vegetable foods in the intestine. The first is their bulk; the second is the amount of cellulose which they contain. If the bulk be small and the proportion of cellulose scanty, digestion is very complete. White bread, macaroni, and rice fulfil these conditions, hence the small proportion of them which escapes absorption. On the other hand, if the food be bulky and full of cellulose, digestion and absorption are much less perfect. Unfortunately, the majority of vegetable foods more or less correspond to this description, and hence the proposition as originally laid down is true of the majority of them, namely, that they are not so completely digested and absorbed as animal foods are.

The property of **bulkiness** is one common to the majority of vegetable foods. As already indicated, it is to be attributed in a great measure to the amount of water and starch which they contain. Considering that upwards of four-fifths of the weight of all green vegetables and fruits is due to water, and that even the drier forms, such as split peas, take up about three times their weight of water in the process of cooking,² it is not to be wondered at that vegetable foods must be bulky out of all proportion to the amount of nutriment which they contain. To this rule bread is almost the sole exception, containing as it does fifty-six parts of dry matter in every hundred. Hence, bread must of necessity enter largely into any purely vegetarian diet if the bulk of the latter is to

¹ Compiled from the figures of Voit, *Zeit. f. Biolog.*, 1889, xxv. 232.

² Half a pound of split peas boiled to a thick porridge weighs 2 pounds.

be kept within reasonable limits. Even then a vegetable diet remains of much larger volume than a purely animal or even a mixed diet. The difference is graphically brought out in Fig. 11, where the bulk of an equivalent amount of each kind of diet is exhibited in proper relative proportion.¹

800 ANIMAL

1300 MIXED

2700 VEGETABLE

FIG. 11.—RELATIVE BULKS OF AN ANIMAL, A MIXED, AND A VEGETABLE DIET (IN CUBIC CENTIMETRES).

This bulkiness of vegetable food interferes with its digestion in two ways. First, it is difficult for the digestive juices thoroughly to penetrate such a mass, hence the conversion of the nutritive constituents into forms suitable for absorption is apt to be inefficiently carried out; secondly, the large bulk of food stimulates and hastens the movements of the intestine, and the contents of the latter are thus hurried on, and less time allowed for absorption to take place. It is to compensate for this that herbivorous animals have a much longer intestine than the carnivora.

The other great obstacle to the complete digestion and absorption of vegetable foods in the intestine is the presence of cellulose.

The reasons for this have been already to some extent explained (p. 162). Cellulose is very imperfectly attacked by the digestive apparatus of man and other carnivorous animals. Indeed, only while it is still very young and tender is it capable of solution to any extent.² In this condition an amount varying from 4 up to 60 per cent. or so of the cellulose in the food may disappear in the course of digestion.³ But it is exceedingly doubtful whether even this amount is really made use of as food. Part at least of it seems to be converted by the action of bacteria into marsh gas and lost to the body.⁴

¹ See Voit, *Zeit. f. Biolog.*, 1889, xxv. 232.

² Meyer, *Zeit. f. Biolog.* 1871, vii. 1.

³ Atwater has constructed a table (p. 168) showing the degree to which cellulose was digested and absorbed in experiments on men. Lorisich, however, finds (*Zeit. f. Physiol. Chem.*, 1908, xlvii. 200) that healthy persons absorb about 60 per cent. of cellulose. In cases of chronic constipation the absorption rises to 80 per cent., whilst in fermentative indigestion it falls to 20 per cent. He thinks that its solution must be brought about by a special ferment in the intestine, and not result entirely from bacterial action, as has hitherto been supposed.

⁴ Hoppe Seyler (Schäfer's 'Textbook of Physiology,' i. 470).

Cellulose,¹ then, influences digestion and absorption in several ways. It is not only almost useless for purposes of nutrition itself, but prevents the access of the digestive juices to the nutritive ingredients which it encloses, unless it has been thoroughly broken up in the preparation of the food. More than this, being itself unabsorbed, it goes to swell the bulk of the already unwieldy mass which vegetable food forms in the intestine, and takes part in that stimulation of the movements of the bowel which is an additional difficulty in the way of absorption. It is for this reason that foods rich in cellulose, such as brown bread, fruits, and green vegetables,

¹ CELLULOSE DIGESTED IN EXPERIMENTS WITH MEN.

Food used (Quantities per day in Grammes).	Water-free Substance in Food.	CELLULOSE.		
		In Food.	In Fæces.	Undigested.
	Grms.	Grms.	Grms.	Per cent.
Potatoes, 1,700 grammes; fat, 100 grammes; beer, 500 c.c.; gluten, 200 grammes	—	5·6	1·2	22·0
Potatoes, 1,700 grammes; fat, 100 grammes; beer, 500 c.c.	—	4·8	1·0	21·1
Celery, cabbage, carrots—total, 1,050 grammes	139·0	12·5	4·7	37·3
Celery, cabbage, carrots—total, 883·3 grammes	117·8	10·4	5·5	52·7
Bread, fruit, dry fruit, oil—total, 1,802 grammes	719·0	16·0	9·2	56·0
Bread, fruit, dry fruit, oil—total, 1,764·8 grammes	692·5	16·7	6·3	37·0
Rice and barley, salted radish, vegetables—total, 2,150 grammes	523·8	17·4	4·2	24·0
Rice, salted radish, vegetables, etc., fish—total, 1,800 grammes	615·7	4·6	0·8	17·5
Rice, salted radish, vegetables, etc., meat—total, 1,500 grammes	580·1	6·0	0·5	8·6
Wheat and rye bread (with yeast), 1,000 grammes	616·3	4·3	2·5	63·1
Wheat and rye bread (with yeast), 900 grammes	554·6	3·9	2·0	50·1
Wheat and rye bread (leavened), 1,000 grammes	619·1	4·7	3·3	70·0
Wheat and rye bread (leavened), 900 grammes	557·2	4·3	1·5	36·4
Decorticated (entire) rye bread (with yeast), 1,000 grammes	647·3	8·2	3·7	45·2
Decorticated (entire) rye bread (with yeast), 900 grammes	582·6	7·4	4·1	55·9
Decorticated (entire) wheat bread (with yeast), 1,000 grammes	640·8	6·7	3·7	55·4
Rye bread (with yeast), 1,000 grammes	623·0	8·2	4·9	59·7
Rye bread (with yeast), 900 grammes	570·0	7·6	4·8	63·9
Wheat bread (with yeast), 1,000 grammes	640·2	8·9	4·2	47·4
Wheat bread (with yeast), 900 grammes	576·3	8·1	3·8	46·6

are recognised as useful in the diet of those who suffer from sluggish action of the bowels. Even for healthy persons, a moderate amount of cellulose in the food is a useful intestinal stimulant. Purely carnivorous animals, on the other hand, do not appear to require it at all, whereas for the herbivora, owing to their long and sluggish intestine, its presence in the food is a necessity of life.

This incompleteness of absorption, which is the characteristic of most vegetable foods, affects in different degrees their different nutritive constituents. The fats appear to be hardly affected by it.¹ Cocoa-butter is as well absorbed as ordinary butter, and olive oil as cod-liver oil. Starch and sugar also are digested and sucked up into the blood almost to the last particle. It is only when considerable quantities of green vegetables or of such foods as peas and beans are taken that one finds any undigested starch grains in the excreta of healthy persons.² It would appear, in fact, that the proteins have to bear almost alone the brunt of the defective absorption. Why the proteins of vegetable food should be so much less completely absorbed than the other ingredients, it is somewhat difficult to say; but the results of all experimenters are at one in showing that a relatively larger amount of nitrogen is excreted by the bowel on a vegetable than on an animal diet.

In the table a number of such experiments, which were all carried out on healthy persons, have been collected, and the percentage of protein which escaped absorption in each food compared with that in meat. It will be observed that all the vegetable foods exhibit a much greater loss of protein than meat does.

RELATIVE ABSORPTION OF PROTEIN IN VARIOUS FOODS.

Diet.						Protein not Absorbed.
Meat ³..	..	..	..	..	..	2·3 per cent.
Lentil flour (218 grammes daily) ⁴	..	..	..	..	..	10·5 "
Dried peas (600 "	..	..	..	..	..	17·0 "
Beans (500 grammes)	}	..	..	..	..	30·3 "
Flour (17 "						
Potatoes (3,000 grammes) ⁷	..	..	..	..	..	32·0 "
Carrots and fat (412 grammes, dried) ⁸	..	..	..	..	..	39·0 "
Lentils (250 grammes, simply soaked and boiled till soft) ⁹	..	..	..	..	..	40·0 "

¹ See experiments by Bourot and Jean and by Blumenfeld (*Fahres-Ber. über Thier-Chem.*, 1896, xxvi. 58, and 1895, p. 46), also Bendix (*Therap. Monatshefte*, 1895, ix. 345).

² See Moeller, *Zeit. f. Biolog.*, 1897, p. 91.

³ Rubner, *Zeit. f. Biolog.*, 1879, xv. 121, 125.

⁴ Strümpell, *Deut. Archiv. f. Klin. Med.*, 1876, xvii. 108.

⁵ Rubner, *Zeit f. Biolog.*, 1880, xvi. 127, 128.

⁶ Prausnitz, *ibid.*, 1890, xxvi. 227.

⁷ Rubner, *ibid.*, 1897, xv. 147, 160.

⁸ *Ibid.*

⁹ *Loc. cit.* (2).

In a number of prison diets of an exclusively vegetable nature, in which the protein ranged from 106 to 56 grammes, or, if bread were excluded from the reckoning, from 41 to 2 grammes daily, it was found¹ that on an average from 25 to 47 per cent. escaped absorption. Schuster also observed,² in Houses of Correction where bread, pulses, potatoes, and green vegetables were given, and only 60 grammes of meat three times in the week, that, of the 104 grammes of protein supplied, only 78 grammes (72 per cent.) were absorbed, but that in prisons where 116 grammes of meat and only three-fifths as much vegetables were supplied, 87 per cent. was absorbed. Some later observations, however, have yielded more favourable results. Thus, in the case of a girl who lived upon a diet consisting exclusively of fruit and nuts, absorption was found to be practically equal to that which obtains on a mixed diet,³ and a study of two individuals who lived upon fruits, nuts, and vegetables gave a similar result.⁴ It is true that there was a somewhat greater loss of nitrogen from the bowel in these cases than one finds on a mixed diet, but this was almost balanced by a lesser excretion of nitrogenous constituents in the urine.

It would appear that the mere presence of a large amount of starch in the intestine is *per se* unfavourable to the absorption of protein.⁵ This is probably to be attributed to the fermentation of part of the starch, and the production of acids which unduly quicken the intestinal movements; on the other hand, a moderate degree of such acid production ought to be actually favourable to the absorption of protein, by restraining the growth of putrefactive germs in the intestine, which would speedily break up the proteins of the food and carry them past the stage in which they are available as foods. Doubtless, also, the effects of cooking are less favourable to the digestion of protein than to that of starch. Under the influence of heat and moisture, the starch grains swell and rupture and burst through the walls of cellulose which enclose them, but under similar circumstances the protein in the vegetable cells is coagulated and shrinks away from its wall of cellulose, so that the latter is likely to remain unruptured. There are some⁶ who go so far as to say that the large amount of nitrogen found in the intestinal excreta on a vegetable diet is not derived from unabsorbed protein, but from the

¹ Hofman, 'Die Bedeutung von Fleischnahrung,' Leipzig, 1880.

² Quoted by Munk, Weyl's 'Handbuch der Hygiene,' iii, 116.

³ U.S. Dept. of Agriculture, Off. of Experiment Stations, Bull. No. 107, 1901.

⁴ Caspari and Glaesener, *Zeit. f. Diät. u. Physik. Therap.*, 1903, vii, 475.

⁵ Wicke and Weiske, *Zeit. f. Physiolog. Chemie*, 1895, xxi, 42 and 1896, xxii, 137.

⁶ See Prausnitz, *Zeit. f. Biolog.*, 1897, xxxv, 287.

residue of the digestive juices. On this view of the facts the vegetable foods must require a larger amount of the digestive juices for their solution than the animal foods do. Even if we accept this explanation as in part, at least, correct, the fact remains that relatively more nitrogen is lost from the bowel on vegetable than on animal food, and from this, as we shall see shortly, various practical consequences can be deduced.

3. THE NUTRITIVE VALUE OF VEGETABLE FOODS.

There is reason to suppose that the vegetable proteins are not of the same value for tissue-building purposes as proteins of animal origin.¹ The reason is that the protein molecule is built up of a number of fragments composed of different amino-acids. When proteins are disintegrated in the process of digestion, these fragments are liberated, and, after absorption, are regrouped to constitute the appropriate proteins of the body tissues. But the amino-acids in vegetable proteins are not present in the same relative proportions as those found in animal proteins, and consequently when vegetable protein is converted into body protein there is apt to be considerable waste, for an excess of the vegetable protein has to be broken up in order to provide those amino bodies which are relatively more abundant in the animal. Thus it has been found by Thomas that the following are the smallest amounts of different food proteins required to protect body protein from 'loss':²

Meat protein ..	..	30 grammes.	Bean protein ..	..	54 grammes.
Milk „ ..	..	31 „	Bread „ ..	..	76 „
Rice „ ..	..	34 „	Maize „ ..	..	102 „
Potato „ ..	..	38 „			

The most valuable proteins for repair purposes, therefore, are those of the animal class.

On the other hand, as far as fuel value is concerned, the vegetable and animal proteins appear to be equal; or, if anything, it is vegetable protein which yields the greater amount of heat on combustion.

As regards the carbohydrates nothing need be said. **Starch and sugar** are of necessity derived almost entirely from vegetable sources, and their high nutritive value is beyond dispute.

As regards **fat** also, the daily experience of the Southern European

¹ See Gowland Hopkins, 'Recent Advances in Science' (Huxley Lecture), *Lancet*, January 1, 1921. Plimmer, 'Quality of Protein in Nutrition,' *ibid.*, April 30, 1921. E. V. McCollum, 'The Newer Knowledge of Nutrition,' New York: The Macmillan Company, 1919.

² See Lusk, 'The Fundamental Basis of Nutrition.' Yale University Press, 1914, p. 20.

countries is confirmed by scientific experiments, which show that vegetable fats, such as olive oil and cocoa-butter, are as valuable as means of nourishment as the fats of meat or milk.¹

But we must by no means suppose, even if the chemical constituents of vegetable food were equal in nutritive value to the corresponding constituents of animal food, that therefore vegetable food as a whole can replace meat, and *vice versa*. The form in which the nutritive ingredients are presented to the digestive organs materially affects their utility as foods. A glass of whisky is chemically the same whether it be taken 'neat' or diluted with a tumblerful of water, but the effects on the body are radically different.

The question, therefore, presents itself: Is it better to obtain the nutritive constituents of our food in an animal or a vegetable form? and an attempt to reply to this question raises the whole problem of **vegetarianism**. With that problem we must now concern ourselves for a short space.²

Vegetarianism may be advocated either on physiological or on economic grounds.

As regards the **physiological argument**, it may be pointed out—what is apt to be lost sight of—that the vegetarian question is really a question of protein, and of that alone. The carbohydrates of the diet must almost perforce be derived from the vegetable kingdom, for there alone are they to be found in any quantity, and it has already been pointed out that the fat of the diet may be obtained with equal physiological advantage from either an animal or a vegetable source.

But as regards proteins it is different. Even were a given quantity of pure vegetable protein fully equal in nutritive value to a similar quantity of the protein of flesh, we are still unable to extract the vegetable protein in a state of purity and eat it by itself, but must take it in the form in which it is presented to us by Nature. The real question, therefore, is: Shall we eat our protein in an animal or a vegetable form? Now, in the first place, it will scarcely be denied that vegetable foods are relatively much poorer in protein than animal foods are. Contrast typical examples of both kingdoms after the removal of water, for that is the only fair method of comparison, and one arrives at the following results:

¹ See references in footnote, p. 169.

² For a full scientific discussion of vegetarianism, see Ferdinand Hueppe, 'Der Moderne Vegetarianismus' (Berlin, 1900); Albert Albu, 'Die Vegetarische Diät' (Leipzig, 1902); and Stachelin, 'Untersuchungen über Vegetarische Diät,' *Zeit. f. Biologie*, 1907, xlix. 199.

100 parts of dried lean beef contain	..	..	89 parts of protein.
" " fat beef contain	..	..	51 " "
" " pea flour	..	..	27 " "
" " wheat	..	..	16 " "
" " rice	..	..	7 " "

The comparison shows that even the fattest meat is far richer in protein than the most nitrogenous forms of vegetable food.

Not only so: what protein is present in vegetable food has its value still further lowered in many cases by the defective nature of its absorption in the body. The truth of this has been already sufficiently demonstrated.¹

It must be obvious from all this that vegetable food, unless eaten in large quantities, will not yield a sufficiency of protein to the body. The important question arises, therefore: How much protein does a healthy man require in his food daily? This question has been discussed in an earlier chapter, and it is only necessary to remind the reader that the amount of protein which is required daily by a healthy man doing a moderate amount of bodily work has been estimated at about 100 grammes.² And what are the consequences of living upon a diet which contains less protein than this? To this question, as we have also seen (p. 23), it is not easy to give an altogether satisfactory reply. In the first place it must be admitted that such a large amount of protein is by no means necessary for making good the mere daily waste of protein in the body. Very much less will suffice for that, and carefully-conducted experiments have shown that no impairment of the stock of protein in the body is incurred even if the amount in the food be cut down to as low a level as 60 grammes daily. Even if it be objected to such experiments that this minimum consumption of protein has only been maintained for very limited periods, yet it may be replied that the minimum reached is not much below that which forms the average daily consumption per individual in a large number of healthy races, such, for example, as the Japanese.³ The

¹ See also Porter, 'Animal versus Vegetable Protein,' *New York Med. Journ.*, January 8, 1921, p. 47.

² It is not improbable that the minimum amount of protein on which life can be healthily maintained varies in different individuals, and that, therefore, the question, How much protein is required daily? admits of no categorical reply. Perhaps the closest approximation to a solution of the problem which the present state of scientific knowledge admits of is comprised in the statement that of the total amount of energy which the diet contains something between 10 and 15 per cent. should be supplied in the form of protein. Bornstein (*Zeit. f. Physik. und Diät. Therapie*, xvi., 1912, p. 24) is of opinion that from 70 to 80 grammes of protein daily are sufficient in a mixed diet, and 60 to 70 grammes on a meat-free diet.

³ It may be fairly objected to this statement that the average individual in such races is of much smaller body-weight than the ordinary European.

reply of scientific experiment, therefore, as far as it can be applied to the problem under consideration, would be that it is undoubtedly possible to maintain a healthy life upon such a daily amount of protein as is contained in a moderate quantity of vegetable food, and the accumulated experience of vegetarian races fully bears this out.

This, however, does not dispose of the question. There is such a thing as **degrees of health**. While one freely admits that health and a large measure of muscular strength may be maintained upon a minimum daily supply of protein, yet I think that a dispassionate survey of mankind will show that races which adopt such a diet are lacking in what, for want of a better word, one can only describe as *energy*. Now, **energy** is not to be confused with muscular strength. A grass-fed cart-horse is strong; a corn-fed hunter is energetic. Energy is a property of the nervous system; strength, of the muscles. Muscles give us the power to do work; the nervous system gives us the initiative to start it. Muscles do their work upon carbohydrates, which are the characteristic nutritive constituent of vegetable foods; the brain appears to require nitrogen, which can only be obtained in a concentrated form from animal sources. If protein food, therefore, be regarded as a nervous food, a diet rich in it will make for intellectual capacity and bodily energy, and it is not without reason that the more energetic races of the world have been meat-eaters.

The Scottish peasants are often adduced as an example of a high degree of energy and intellectual capacity produced from a vegetable diet. But this is the very exception which proves the rule, for the Scottish peasant of the last generation was not only fed on a highly nitrogenous form of vegetable food—oatmeal—but the protein of this was still further supplemented by the addition of milk, of which 2 to 3 Scots pints (each equal to $3\frac{1}{2}$ imperial pints) used to be allowed to each family daily in the form of wages.

The difference, in fact, between an animal fed on a highly nitrogenous diet and one supplied with little nitrogen is the difference between a steam-engine at half-pressure and one which is producing its full horse-power. It is the difference between a tiger pacing its cage and a cow lying upon the grass; both are healthy, but the type or degree of health is very different in the two cases.

‘The hunted deer,’ says Haughton, ‘will outrun the leopard in a fair and open chase, because the work supplied to its muscles by the vegetable food is capable of being given out continuously for a long period of time; but in a sudden rush at a near distance, the leopard

will infallibly overtake the deer, because its flesh food stores up in the blood a reserve of force capable of being given out instantaneously in the form of exceedingly rapid muscular action.'

Not only, I think, does a diet rich in protein make for physical and mental energy: it seems to increase also one's **power of resisting disease** (see also p. 180).

An abundant supply of protein seems to be necessary if the blood and muscles are to be kept in good condition, and by promoting oxidation it increases vigour and diminishes the tendency to an undue accumulation of fat. The nervous system, too, seems to require a plentiful supply of protein if those mysterious influences which emanate from the brain and spinal marrow are to be maintained with sufficient potency to enable the tissues to ward off the inroads of disease.

To growing children a deficiency of protein in the diet is specially disastrous, for the lack of building material which it entails may result in impaired growth and development, the consequences of which may last throughout life.

For the same reason persons who habitually live on a minimum of protein are apt to convalesce but slowly after an acute illness, for once their tissues are broken down, they have no ready surplus of building material out of which to repair them.¹

Everyone knows the feeling of well-being which follows a meal containing meat. That this is due to the protein in meat, and not to its extractives, is shown by the fact that whereas the addition of the extractives of meat to foods, such as bread, is unable to produce this feeling, yet such vegetable substances as oatmeal, which are rich in protein, are capable of exciting it in a considerable degree. A full meal of nitrogenous food is an actual stimulant to the tissues of the body, and is of value even if it only comes at long intervals, for its good effects would appear to be not altogether of a transient nature. This stimulation of the tissues must also make for resisting power.

Of course, there is another side to all this, and the consumption of an excess of nitrogenous food is not free from dangers. At the present time there is no great likelihood that the English-speaking races, at least, will suffer from a deficiency of nitrogen in their food. The danger, indeed, is all the other way, in the direction of a too liberal consumption of meat. It is for insisting upon the disadvantages of such a course, and on the feasibility of living upon a diet from which meat is altogether excluded, that we in this

¹ There is reason to believe that the disease pellagra is induced by a diet containing insufficiency of protein, or at least protein of poor biological quality (for literature see footnote 1, p. 171).

country owe even the extremest vegetarians a considerable debt of gratitude; and if the above objections to living upon a minimum of protein can be shown to be groundless, as Chittenden and his followers believe, then the objections to a purely vegetarian diet largely disappear also.

Granted, then, that the consumption of only a moderate quantity of purely vegetable food is apt to mean a lack of protein in the diet, with all its attendant risks, we have next to ask, How may this deficiency be supplemented? The reply is that this may be effected in one of three ways:

1. The **mixed feeder** solves the problem by adding to a considerable basis of vegetable material a moderate amount of food obtained from animal sources. Meat and fish are concentrated forms of protein food, and by their use he is able to supplement the comparatively small amount of nitrogen contained in the rest of his diet.

What the ideal **proportion between the vegetable and animal constituents** of a mixed diet should be it is a little difficult to say. Voit considers that 35 per cent. of the total protein required daily should be taken in an animal form. This would be represented in an ordinary diet by 7 ounces of meat (two moderate-sized platefuls). If the proportion of animal protein is habitually three-fourths of the total, it is considered by many that there is a danger of producing disease, especially gout.

Actual observation of eighty-seven dietaries in the United States showed that, of the total food consumed, 45 per cent. was in an animal, and 55 per cent. in a vegetable, form. The former proportion is probably too high, and in all likelihood we shall not be far wrong if we reckon that an ordinary diet should contain one part of raw animal food to every three parts of uncooked vegetable material. This relation is pretty nearly observed in the relative proportions of meat and bread in an ordinary sandwich. It is obvious, however, that the exact proportions must vary somewhat with the form in which the vegetable food is taken.

2. There is a special class of 'vegetarians' who supplement the protein of their diet from two animal sources only—**eggs and milk**.¹ That these are both well adapted to supply protein we have already seen, but their superiority to meat and fish is not so evident. A diet of this sort has been investigated by Cramer.² It consisted of whole-

¹ This is sometimes called the 'V. E. M.' diet, from its consisting of vegetables, eggs and milk. The term was first introduced by the late Professor Jarrett, of Cambridge (see Newman's 'Essays on Diet').

² *Zeit. f. Physiolog. Chemie*, 1882, vi. 346.

meal bread, potatoes and fruit, with the addition of eggs and milk. The consumer was a so-called vegetarian of eleven years' standing. The diet contained altogether only 74 grammes of protein, of which rather more than one-third was derived from the eggs and milk. It was therefore deficient in protein (according to the ordinary standard) to start with, and not only so, but fully 21 per cent. of the protein was found not to be absorbed.

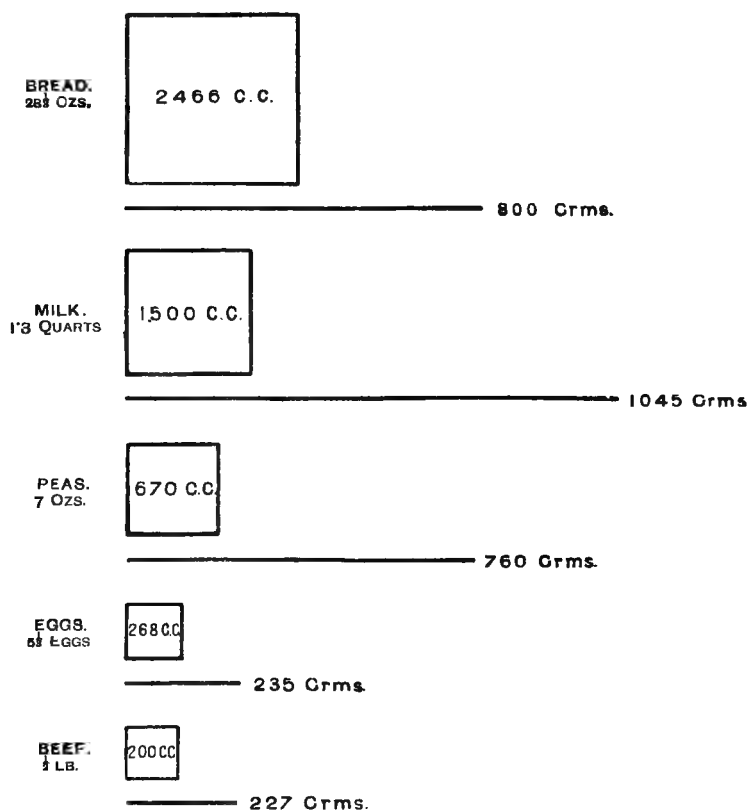


FIG. 12.—BULK AND WEIGHT OF DIFFERENT FORMS OF FOOD YIELDING THE SAME QUANTITY OF PROTEIN.

A more liberal use of milk might have remedied the defects in this diet, and it would then be open to no physiological objection, except the difficulty (and often the expense) of obtaining a sufficient supply of milk. The addition of cheese would also be an advantage.

There is no doubt that this modified form of vegetarianism has much to recommend it, and it often agrees better with gouty persons

than a diet into which meat enters in any large amount.¹ The great development in the manufacture of casein products in recent times has made the adoption of such a diet a comparatively simple matter (see also p. 544).

3. To the **consistent vegetarian** the only available method of increasing the proportion of protein in his diet is by increasing the total amount of food consumed, and especially by having large recourse to those vegetable substances, such as the pulses, which are specially rich in nitrogen.

Let us suppose that dry lentils are selected as the protein-carrier. It would take 450 grammes of these to supply the total protein required daily, and this quantity must be further increased to 500 grammes in order to allow for the loss of 10 per cent. of protein from defective absorption, and when cooked into a thick porridge the total weight of the mass would be 2,000 grammes. Now, this is a very formidable figure when one remembers that only 600 grammes of cooked meat would be required to supply the same amount of protein.

In the preceding diagram (Fig. 12) the bulk and weight of different forms of cooked animal and vegetable food required to yield the same amount of protein are contrasted, and it conclusively demonstrates the superiority of eggs and meat as compact sources of nitrogen even over milk, and still more over such vegetable foods as bread and peas.

The conclusion, therefore, seems justified even on a *priori* grounds, that, if one attempts to obtain the usual supply of protein in a purely vegetable form, he must be prepared to consume a rather bulky diet. Actual observation confirms this. Even the above-mentioned 'vegetarian' consumed about 2,960 grammes (about 6½ pounds) of cooked food daily. If he had replaced the eggs and milk in his diet by vegetable foods, the total quantity would have risen to nearly 3,500 grammes. Seeing that the total capacity of an ordinary stomach is only about 1,200 grammes² (2¾ pounds), this means that the stomach must be filled to the limit of its capacity thrice in the day. And yet even then we saw that only 74 grammes of protein would be ingested.

The causes of this **inevitable bulkiness** of a purely vegetable diet have already been dwelt upon and have been shown to depend on the wateriness of vegetable food, especially when cooked, and on the large amount of indigestible cellulose which it contains, to

¹ See Haig's 'Diet and Food,' London, 1898.

² See Hofman, 'Die Bedeutung von Fleischnahrung.'

which may be added that the small amount of protein present is diluted, as it were, by a disproportionate quantity of starch. Hence, in order to get a sufficiency of protein in a purely vegetable diet, one is obliged to consume much more starch than is really required. The physiological effects of this excessive bulk now call for some consideration.

One of the first results of the habitual ingestion of a bulky diet is that the stomach and bowels become somewhat distended. Examples of this are found in the disproportionate abdominal development of cattle and other herbivora, and in the so-called 'potato-belly' of the Irish peasant. This distension has the effect of increasing the capacity of the stomach so that more food can be taken. Indeed, until this increase in capacity has taken place there is difficulty in consuming a sufficiency of purely vegetable food to meet the demands of the body. For this reason the adoption of a vegetable diet is useful in some forms of obesity, especially when complicated by habitual constipation. The treatment involves a species of fraud upon the body, the distension of the stomach producing a feeling of satiety before a sufficiency of nutriment has really been taken in. Unfortunately, the increase in capacity of the abdominal organs, by which the greater bulk of a vegetable diet is compensated for, does not seem to be accompanied by an increased power of digestion and absorption. Observations made upon vegetarians of several years' standing by Voit¹ and by Cramer² showed that the amount of food which escaped digestion in these subjects was quite as great as one finds it to be in those who have but recently adopted that form of diet. Indeed, one of the results most commonly observed to follow the habitual use of purely vegetable food is an enfeeblement of the digestive organs and a tendency to chronic diarrhoea. The reason for this is, perhaps, that the very bulkiness of vegetable food, and its tendency to undergo acid fermentation, causes it to be hurried through the small intestine into the larger bowel, where absorption is much less active. Thus, one finds that whereas the average amount of material evacuated daily from the large bowel on an animal diet amounts to 120 grammes, it reaches 333 grammes in the case of a purely vegetable feeder.³

The very necessity for the manipulation by the stomach and bowels of such a large mass of material constitutes another of the disadvantages of a purely vegetable diet. For such manipulation

¹ Voit, *Zeit. f. Biolog.*, 1889, xxv. 232.

² Cramer, *Zeit. f. Physiolog. Chemie*, 1882, vi. 346.

³ Voit, *Zeit. f. Biolog.*, 1889, xxv. 232.

involves greater muscular effort on the part of the stomach and intestinal walls, and that implies a **large expenditure of blood and of nervous energy**. There is thus less of these left for other purposes, and especially for the use of the brain, hence the feeling of lassitude always experienced after a heavy meal. This prostitution of nervous energy, from higher purposes to the mere manipulation of food which vegetarianism involves, is another reason for regarding that mode of life as a retrogression in civilization. The more concentrated (within reasonable limits) we can manage to make our food, the more easily is it appropriated by the body, and the greater is the amount of energy which we have to spare for our intellectual and other needs.

It must be added, lastly, that the **wateriness**, which is such a pronounced characteristic of vegetable food, is itself a disadvantage. Observation even shows¹ that it does not, as is often maintained, diminish the amount of water which is drunk. On the other hand, the fluid in the food is absorbed into the blood and retained in the body, rendering its fluids more dilute and its tissues more watery. It is probable that this accounts for the 'soft' condition and flabbiness of those who habitually consume large quantities of the more watery forms of vegetable food. It is doubtless also an important factor in producing the low resisting power which is characteristic of such persons. That this low resistance to disease, to which reference has so often been made, is no mere bogey of the scientific imagination is shown by the history of the epidemics which from time to time break out amongst those who are compulsorily maintained on an entirely vegetable diet.

In concluding this subject, it should be pointed out that the **disadvantages of a purely vegetable diet** affect the outdoor labourer much less than one engaged in more sedentary pursuits. The labourer actually requires a large amount of carbohydrate to enable him to perform his muscular work, and in eating large quantities of vegetable food for this purpose he is almost sure to get as much protein as he requires also. The free action of the skin, too, which his work insures carries off from the body the excess of water which his diet contains, whilst his active work in the open air induces an appetite for large meals.

With the sedentary worker, however, the case is different. He requires much less carbohydrate than the labourer, while his demand for protein still remains considerable; and in endeavouring to obtain from purely vegetable sources a sufficiency of the latter ingredient

¹ See Meyer, *Zeit. f. Biolog.*, 1871, vii. 1, and Rutgers, *ibid.*, 1888, xxiv. 351.

he inevitably overburdens his diet with an excess of the former, which his comparatively feeble digestion is unable to master, while he has no ready means of getting rid of the surplus water which it contains. For this reason the sedentary man is much less likely to be a successful example of vegetarianism than one who leads a more active life.¹ General experience, I think, bears this out.

4. RELATIVE ECONOMY OF VEGETABLE FOOD.

When the relative cost of animal and vegetable food comes to be considered, the advocate of vegetarianism is on much firmer ground. There can be no doubt that **vegetable food is much the cheapest**. This is shown in the diagram to which attention has already been directed (Plate III.), and which exhibits the number of Calories obtained from a shilling's worth of different forms of food. One sees that a given sum yields a far larger amount of fuel for the body when spent on bread, peas, or potatoes, than when invested in eggs, fish, or beef, or even in such comparatively cheap animal foods as cheese and milk.

This superiority of vegetable food applies not merely to the carbohydrates and fats, which are its fuel constituents, but to proteins as well. The following table shows the **cost of 1 pound of protein** when purchased in different forms :

1 pound protein in peas costs	..	..	7d.
" " oatmeal costs	..	..	7½d.
" " bread	"	..	1s. 6d.
" " milk	"	..	2s. 2d.
" " beef	"	..	2s. 8d.

On an average, therefore, one will get about four times as much vegetable as animal protein for a given sum.

A consideration of the respective methods by which plants and animals derive the raw material for building up their tissues will prove that the former must *necessarily* be cheaper sources of food-supply than the latter.

The atmosphere and the soil are the primary sources of all food. The former contains carbon in the form of carbonic acid gas along with water vapour. The latter contains water and nitrogen in the form of nitrates. Now, animals are unable to make use of carbon and nitrogen in these simple forms, but plants can. The plant, aided by the light and heat of the sun, and by water, builds up the carbon of the carbonic acid gas into carbohydrates. These are

¹ The defective appetite of many town-dwellers is a great obstacle to their successful adoption of vegetarianism. The fact that meat adds to the 'tastiness' of the diet is one of its great advantages as a food, and it is for this reason that it is unconsciously sought after. (See also Rubner, 'Volksernährungs Fragen,' p. 86, *et seq.*)

eaten by animals, and broken up by them into carbonic acid gas and water, and returned through the lungs in that form to the atmosphere once again (see Fig. 13). The plant also lays hold of the nitrates in the soil, and works up the nitrogen which they contain along with some

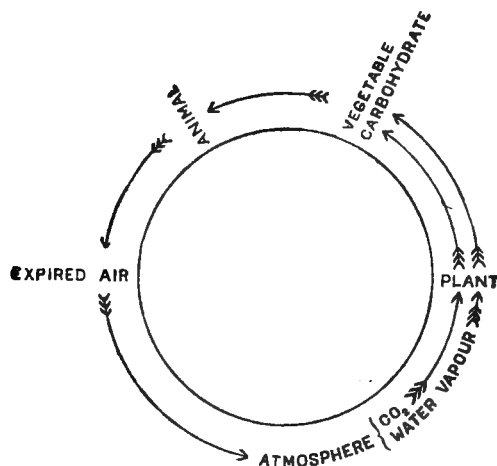


FIG. 13.—CARBON FOOD CYCLE.

of the carbon derived from the atmosphere into complex vegetable proteins (Fig. 14). These also are consumed by animals, and after

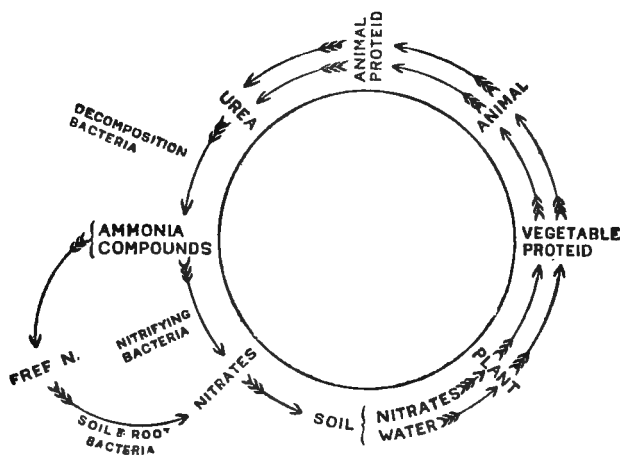


FIG. 14.—NITROGEN FOOD CYCLE.

a brief life as the proteins of muscle and other tissues, are eliminated through the kidneys in the form of urea. By the action of bacteria, the urea is further broken up into compounds of ammonia, and these

in their turn are taken in hand by another set of bacteria, and the nitrogen which they contain converted into nitrates once more.

Not all of the nitrogen, however, is so fortunate. Part of it is split off, and goes to join the immense mass of free nitrogen contained in the atmosphere. There is, then, a certain loss of nitrates from the soil when the latter produces vegetables which are used for animal food. The loss would be greater than it actually is were it not for the existence of another kind of bacteria, whose acquaintance scientific men have but recently made. These establish themselves upon the roots of certain plants, especially the pulses, and perform the kindly office of laying hold of some of the free nitrogen in the air and fettering it in the form of nitrates. Thus they enrich the soil and feed the plant on whose roots they live. In this way the nitrogen food-cycle of the world is completed.¹

It is owing to this constant loss on the part of the soil that farmers are in the habit of using nitrates as a manure for fields from which heavy crops of cereals are continually being taken. In an address by Professor Crookes before the British Association a few years ago he pointed out that the available supply of nitrates is running short, and predicted that dire results would follow upon its complete exhaustion.

One may now naturally ask: Would it not be possible for science to step in, and itself work up the primitive forms of food into those complex forms which animals require, without the aid of plants? In the case of carbohydrates this has already been achieved, for sugar can be built up out of its elements by the chemist as well as by the plant. It is in the case of the proteins, however, which are such expensive forms of food, that an artificial method is most to be desired. But even with respect to them recent research is stated to have been crowned with success, and a form of protein produced which is identical with the same article as manufactured by Nature. It is not likely, however, that these chemical processes can be carried out on a commercial scale. Certainly not for a very long time to come. And yet, were it possible to fix directly the free nitrogen which is waiting in unlimited quantity in the atmosphere, the problem would be half-way to solution. In his address Professor Crookes indicated a method which gives reason to hope that this may yet be done, and the nitrogen of the air be converted into nitrates in the

¹ The reader will find a much fuller account of Nature's chemical food-cycle, and the part played in it by bacteria, in 'The Story of Germ Life,' by H. W. Conn (London: George Newnes, Lim.), chap. iv.

same way as by the action of root bacteria. Though such compounds are of no direct use as food to man, yet they could be used to prepare the soil for abundant crops of grain. Notwithstanding all these scientific conquests, accomplished or imminent, those who do not look forward to the day when foods will be swallowed in the form of compressed tablets need not be filled with despair. It by no means follows because an artificial product is identical with a natural one in composition that therefore it can replace the latter as food. The analyst may pronounce two compounds the same, but the living body can often detect subtle differences which may lead it to make use of the one and reject the other. That, at least, has been the experience with such scientific preparations as 'artificial milk.'

The differences in the mode of feeding of animals and plants respectively, which have been above described, are well summed up in the saying of an eminent French physiologist, that in the main animals are *analytical*, and plants are *synthetical*, feeders. And seeing that this is the case, seeing that animals must have complex compounds as their nutriment, and that these can only be derived either from vegetables or from the flesh of other animals, it follows that the former must be a much cheaper source of supply than the latter. The difference is exactly the same as between dealing with a manufacturer direct and through the medium of a middle-man. In converting vegetable compounds into flesh an animal takes toll of them. It has its commission, which must be paid by the individual who consumes the flesh and by the community. That the commission amounts to a considerable percentage of the original vegetable food is not open to dispute. 'It is not extravagant to say,' writes one author, 'that every acre well cultivated would feed seven times as many men by its crops as could be fed on the flesh of cattle who do but graze on its spontaneous grasses ;'¹ and the same writer asserts that it has been found in a vast pig butchery at Cincinnati that the oatmeal used in fattening the pigs would have gone nearly four times as far as the pork produced went in feeding mankind.² Another investigator has calculated that 2½ acres devoted to the production of mutton will support one man a year, whilst the wheat grown on the same area would support sixteen men.³ Without committing ourselves to the literal correctness of such calculations, we may yet believe that they are a close approximation to the truth, and the economic questions which they suggest are of far-reaching national

¹ Newman, 'Essays on Diet,' p. 4.

² *Ibid.*, p. 3.

³ Hunter, 'Dietetic Reformer.

importance. But however this may be from the point of view of a nation as a whole, individuals in civilized countries are always found to be willing, when they are able, to pay for animal food the high price demanded for it, by reason of the imperious necessity of obtaining a concentrated form of nitrogenous food. From the individual point of view, too, it must be remembered that there is an offset to the comparative cheapness of vegetable food in the larger amount of cooking which such a diet entails. One scientific writer,¹ who inquired into this point in his own case, found that a mixed diet cost him 2s. 7½d. per diem, while a purely vegetable diet cost 2s. 3d.; but the former required only eighteen and a half hours' cooking in the week, the latter sixty-three hours. Assuming that the fuel cost ½d. per hour, this would mean that the cost of the mixed diet, plus cooking, was 19s. 1½d. per week, as compared with 18s. 4d. for the vegetable diet—a difference which is very slight. If these figures be at all correct, it is not true to say, as some have done, that the abandonment of meat is equivalent for a working man to a rise of 5s. a week in his wages.

In conclusion it may be well to summarize the main points in the argument which has been pursued in this chapter :

1. Vegetable foods are rich in carbohydrates, and, with a few exceptions, comparatively poor in protein and fat. They are also bulky, partly from their richness in starch, but also from the presence of cellulose and a large amount of water. Even if compact in their raw state, they tend to take up much water and to become bulky on cooking.

2. Animal foods are rich in protein and fat, but, with the exception of milk, poor in carbohydrates. They are compact in form (again with the exception of milk), and tend to become more so on cooking.

3. Vegetable foods are less digestible in the stomach, and on the whole less completely absorbed than animal foods, partly by reason of their bulk, partly because of the indigestible coating of cellulose which invests their nutritive constituents, and in part also from their tendency to undergo fermentation in the intestine, with the production of acids which hasten on peristalsis. Their protein constituents suffer more from defective absorption than any other ingredient.

4. Both from chemical composition and from defective absorption a purely vegetable diet is apt to be deficient in protein, and the protein which it does contain is of poorer 'biological value' than animal protein, and of less use for purposes of repair.

¹ Rutgers, *Zeit. f. Biolog.*, 1888, xxiv. 351.

5. The consistent vegetarian must either live upon a diet which is relatively poor in protein or else consume an excessive bulk of food.

6. The adoption of the former of these courses, there is reason to believe, tends to diminish energy and the power of resisting disease; the latter is apt to lead to derangement of the stomach and bowels.

7. Both of these results may be avoided by supplementing the vegetable part of the diet by animal substances rich in protein, but two-thirds of the total protein can safely be taken in the vegetable form.

8. Either meat, fish, eggs, milk or cheese may be used as the protein-carrier, but for healthy persons the moderate use of the first two has certain advantages. For the gouty, perhaps milk and cheese are more to be recommended, while skim or butter milk, salt fish, and the cheaper kinds of cheese are undoubtedly the most economical.

9. Vegetable foods have certainly the advantage of being cheaper, both as sources of building material and energy, than the animal foods are, and vegetarianism may therefore be recommended on grounds of economy, both national and individual. The reasons for the inevitable costliness of foods of animal origin have been pointed out; the cost of cooking, however, must not be lost sight of in this connection, and modifies somewhat the above considerations.

10. It may finally be added, though these points were not dwelt upon, that vegetable foods are less highly flavoured than some animal foods, such as meat, but have the advantage of not being liable to undergo putrefaction, and of rarely producing disease.

The therapeutic uses of a vegetable diet will be described in another chapter (p. 544).

CHAPTER XI

THE CEREALS : WHEAT—BREAD

IN the present chapter we begin the study of the vegetable foods in detail. In classifying these, it is better to be guided by practical convenience rather than by strict botanical considerations, and we may accordingly group them under the following heads :

1. The cereals, *e.g.*, wheat, oats, maize.
2. The pulses, *e.g.*, peas, beans, lentils.
3. The roots and tubers, *e.g.*, carrots, turnips, potatoes.
4. Green vegetables, *e.g.*, the cabbage.
5. Fruits and nuts, *e.g.*, the apple and walnut.
6. Fungi and algæ, *e.g.*, mushrooms and Irish and Iceland moss.

In a separate chapter we shall devote some special attention to the different forms in which sugar and spices enter into the diet.

The Cereals.

From the botanist's point of view, the cereals belong to the tribe of grasses. The only part of them made use of as human food is the fruit or seed. In all grasses there is laid up in the seed a store-house of nourishment for the young plant during the early days of its career. It is interesting to note that the effect of cultivation is to encourage the 'foresight' of the parent plant in providing for its young, so that in the cultivated grasses (*i.e.*, the cereals) this store-house becomes very considerable, and by robbing the young plant of it we tap an abundant source of food-supply. In all of them the different nutritive ingredients—proteins, carbohydrates, fat, and mineral matter—are represented, along with a certain proportion of water, which, however, in the ripe state does not amount to more than 10 to 12 per cent. of the whole grain.

The **proteins** vary considerably in kind in the different cereals, and their value as tissue-formers varies also (see p. 171). They average,

like the water, about 10 to 12 per cent. In addition to the proteins, small quantities of other nitrogenous substances (*e.g.*, amides) are present, the amount of which varies in different cereals. They are always more abundant in the growing plant than in the mature condition.

The chief **carbohydrate** present is starch. This makes up from 65 to 70 per cent. of the entire grain. Small quantities of sugar are also met with, but cellulose is not abundant except in the outer protective covering. This fact is of considerable advantage as far as the digestibility of the cereals is concerned.

The proportion of **fat** varies very notably in different members of the group. It is interesting to note that it tends to be most abundant in those cereals which grow in northerly latitudes, *e.g.*, oats, whereas in the cereals of tropical growth, *e.g.*, rice, it is almost absent. In this the cereals seem to follow a general law, for just as the young whale is provided by Nature with a milk specially rich in fat, so the young cereal which has to grow up in a cold atmosphere is supplied with an abundant store of oil.

The **mineral matter** amounts to about 2 per cent. of the grain, lime and phosphoric acid being most abundantly represented, while the organic salts are almost absent. In this respect the cereals resemble the animal rather than the vegetable foods.

Summing up this rapid review, the **general composition of the cereals** may be said to be something as follows :

Water	..	..	..	..	10 to 12 per cent.
Proteins	..	..	..	..	10 " 12 "
Carbohydrates	..	..	..	..	65 " 75 "
Fat	..	..	..	..	$\frac{1}{2}$ " 8 "
Mineral matter	..	..	..	..	2 "

COMPOSITION OF CEREALS.¹

	Water.	Protein.	Fat.	Carbo- hydrates.	Cellu- lose.	Mineral Matter.
Wheat	12.0	11.0	1.7	71.2	2.2	1.9
Oats	10.0	10.9	4.5	59.1	12.0	3.5
" (hulled)	6.9	13.0	8.1	68.6	1.3	2.1
Barley	12.3	10.1	1.9	69.5	3.8	2.4
Rye	11.0	10.2	2.3	72.3	2.1	2.1
Maize	12.5	9.7	5.4	68.9	2.0	1.5
Rice (in the husk = 'paddy')	10.5	6.8	1.6	68.1	9.0	4.0
Rice (husk removed)	12.0	7.2	2.0	76.8	1.0	1.0
" (polished)	12.4	6.9	0.4	79.4	0.4	0.5
Millet	12.3	10.4	3.9	68.3	2.9	2.2
Buckwheat	13.0	10.2	2.2	61.3	11.1	2.2

¹ The table represents the composition of the cereals in their crude form. The figures are compiled from a vast number of analyses, the data contained in the

COMPOSITION OF PRODUCTS DERIVED FROM CEREALS.

	Water.	Protein.	Fat.	Carbo- hydrates.	Cellulose.	Mineral Matter.
Wheat meal	12.1	12.9	1.9	70.3	1.6	1.2
Fine wheat flour ..	13.0	9.5	0.8	75.3	0.7	0.7
Oatmeal	7.2	14.2	7.3	65.9	3.5	1.9
Rolled oats	7.2	15.4	7.2	64.8	3.5	1.9
Barley meal	11.9	10.0	2.2	71.5	1.8	2.6
Pearl barley	12.7	7.4	1.2	76.7	0.8	1.2
Coarse rye flour ..	11.4	15.3	2.1	66.7	2.3	2.2
Finest	11.2	6.7	0.9	80.0	0.8	0.4
Corn meal	11.4	8.5	4.6	72.8	1.4	1.3
„ (fine)	12.5	6.8	1.3	78.0	0.8	0.6
Buckwheat flour ..	14.0	7.1	1.2	75.9	0.6	1.2
Rizine (flaked rice) ..	11.7	7.9	0.5	79.5	—	0.4

The exact proportion of these constituents contained in each cereal is represented in the tables, and in order of their relative richness in each the members of the group may be arranged thus :

Protein.	Fat.	Carbohydrates.	Mineral Matter.
Oats.	Oats.	Rice.	Barley.
Wheat.	Maize.	Rye.	Millet.
Millet.	Millet.	Wheat.	Buckwheat.
Buckwheat.	Buckwheat.	Barley.	Oats.
Rye.	Rye.	Maize.	Rye.
Barley.	Wheat.	Millet.	Wheat.
Maize.	Barley.	Buckwheat.	Maize.
Rice.		Oats.	Rice.

The great preponderance of carbohydrates in all cereals indicates that they should not be eaten alone, but along with other foods richer in fat and protein. This we have instinctively learned to do, and accordingly we make puddings with eggs and milk, and eat bread with cheese or spread it with butter. All cereals are rather deficient in building material, except, perhaps, oats, and none of them can be regarded as an important source of fat. As a group they are extremely well absorbed, ranking in that respect next to,

report on the composition of the cereals exhibited at the Columbian Exposition being freely used (United States Bulletin 45). The protein has been calculated from the nitrogen, using the factor 5.7 for all except barley, maize and buckwheat, where the factor 6 was employed.

and in some cases even above, the animal foods, and this fact, combined with their compactness and richness in nutrients, places them in the front rank of human foods.

WHEAT.

In this country wheat is by far the most important of cereal foods. We are said to consume 6 bushels of it per head of the population every year. A food which is so largely used merits a detailed study.

If a **grain of wheat** be cut into thin slices and examined under a microscope, it will be found to consist of the following parts (Fig. 15):

1. The **germ**, or embryo. This is simply the young plant. It represents about $1\frac{1}{2}$ per cent. of the whole grain.

2. The kernel, or **endosperm**. This consists of two large masses of nutritive material for the use of the embryo. It makes up 85 per cent. of the grain.

3. The **bran**—an outer envelope mainly composed of cellulose impregnated with mineral matter, and designed as a protective covering to the grain, of which it makes up about $13\frac{1}{2}$ per cent.

The chemical composition of the whole grain and of its three components is shown in the following table, constructed chiefly from analyses by Professor Church. It will be noticed that the germ is characterized by its richness in protein and fat, the endosperm by an abundance of starch, and the bran by a preponderance of mineral matter and cellulose. It should be added that the germ is further peculiar in that both its protein and its carbohydrates are chiefly present in a soluble form.

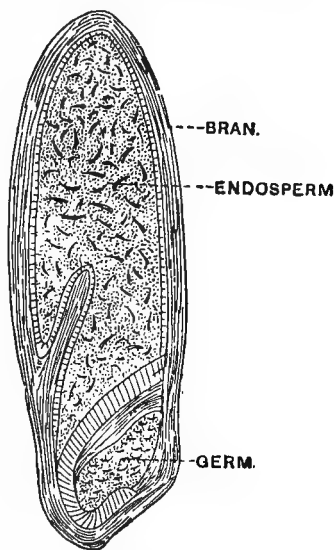


FIG. 15.—LONGITUDINAL SECTION THROUGH A GRAIN OF WHEAT (LOW POWER VIEW).

COMPOSITION OF THE DIFFERENT PARTS OF A WHEAT GRAIN.¹

	Bran (13·5 per cent.).	Endosperm (85 per cent.).	Germ (1·5 per cent.).	Whole Grain (100·0 per cent.).
Water	12·5	13·0	12·5	14·5
Nitrogenous matter ..	16·4	10·5	35·7 ²	11·0
Fat	3·5	0·8	13·1	1·2
Starch and sugar ..	43·6	74·3	31·2 ³	69·0
Cellulose	18·0	0·7	1·8	2·6
Mineral matter	6·0	0·7	5·7	1·7

If the section of wheat be more highly magnified, the structure of its various components can be made out in greater detail. One

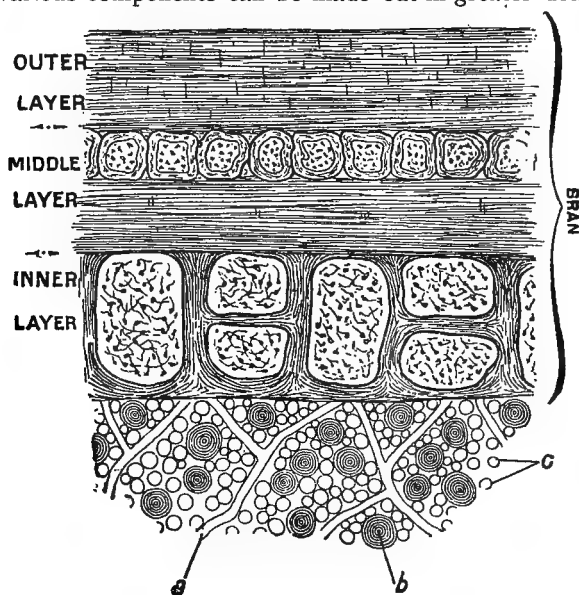


FIG. 16.—SECTION THROUGH PART OF A WHEAT GRAIN (MORE HIGHLY MAGNIFIED).

a, Honeycomb of cellulose; *b*, starch grains; *c*, particles of gluten.

can then see (Fig. 16) that the endosperm consists of a delicate honeycomb of cellulose, the cavities of which are crammed full of starch grains, the interstices being filled up by smaller particles consisting of a protein or mixture of proteins called gluten. The

¹ The first three analyses are by Professor Church.

² The germ contains 6·44 per cent. of nitrogen, of which 0·80 gramme is in the form of amides (Frankfurt, *Landwirth. versuchs Stät.*, 1896, xlvii. 449).

³ Most of this is in a soluble form.

gluten granules are most abundant in the outer zones of the endosperm.

The relative proportions of starch and gluten differ in different kinds of wheat. Generally speaking, it may be said that those grains which look hard, translucent, and horny on section, are rich in gluten and poor in starch; while for the grains which are soft, opaque, and floury on section, the reverse holds good.

The **bran** is found to consist of three distinct layers :

1. An outer layer consisting entirely of fibres of cellulose impregnated with mineral matter. This is the layer which is removed in the decortication of wheat.

2. A middle layer consisting chiefly of small cells full of pigment, which give to the bran its brown colour. This layer is much poorer in cellulose than the first.

3. An inner layer consisting of a single row of large cells full of a granular matter, which is a protein termed *aleurone*. This layer is sometimes also called the 'cerealins' layer. It contains least cellulose of all.

The **germ** consists of a mass of small cells rich in protein and fat, but its more minute structure does not concern us just now.

The wheat grain may be used as a food in its entirety. Soaked in water till it swelled up and burst, and then boiled in milk, with the addition of sugar and other ingredients, it formed the old and very nourishing dish called **frumenty**, which is now, however, but seldom seen on the table.

Far more commonly it is reduced before eating to a state of meal or flour by the process of **grinding or milling**. Now, it is an exceedingly difficult matter, owing to its toughness, to reduce the bran of wheat to a powder by grinding. It can be done, but the trouble and expense entailed are so great that one of the miller's first objects is to remove it altogether. In the old method of stone grinding the bran was removed, but the germ was left, the meal or flour consisting of the products of the germ and endosperm together. In the elaborate processes of modern roller milling, however, the germ also is removed, but for a different reason from the bran. It is found that the oil which is contained so abundantly in the germ is apt to become rancid, so spoiling the flour, while the soluble proteins which are present in that part of the grain are apt to act upon the starch of the flour, converting part of it into soluble forms (dextrin and sugar), which darken in colour in the oven and detract from the appearance of the bread. So the germ is got rid of also, its removal being facilitated by the fact that its toughness causes it to become

flattened out in the process of milling, while the more brittle endosperm is reduced to a fine powder, which can be separated by sifting.

Hence it comes about that in the process of milling, to which the whole grain is subjected, its different parts are broken up, various **mill-products** being produced. The outer coat yields 'bran,' 'fine pollards,' 'sharps' and 'middlings,' which represent different fragments of it from without inwards, the germ is removed as 'offal,' while the 'flour' is derived solely from the endosperm.

To the whole of the **flour** so derived the term 'straight-run' or 'straight-grade' is applied, and the yield of it is about 70 per cent. of the weight of the original grain. By mechanical processes this can be further divided into a small quantity of **patents**, and a large quantity of 'bakers' or 'households.' The former is derived from the central part of the endosperm, and if prepared from ordinary wheat is consequently rather poor in protein, but very rich in starch. Some 'strong' wheats, however, *e.g.*, Hungarian, yield a 'patents' which is still rich in gluten; it is from such flour that genuine Vienna bread is made.¹ Owing to its purity of colour, 'patents' is usually reserved for the preparation of fancy breads and pastry.

'Households' flour is further subdivided into (1) second patents, or 'whites'; (2) first households; (3) second households, or 'seconds.' The first of these is derived from the part of the endosperm nearest to that which produces 'patents'; the last emanates from the outer layers, just under the bran; while the first households comes from the intermediate part of the endosperm. Of these varieties, 'seconds' is richest in protein (gluten), 'whites' in starch.

Ordinary bread is usually made from a mixture of 'whites' and 'households,' derived, most commonly, from a blend of different wheats.

A blend is used because wheats differ in composition, some being rich in gluten and poor in water ('strong' wheats), while others are more starchy and contain more moisture. Indian wheat, which has only about 8 per cent. of water, is an example of the first sort; most English wheats (14 per cent. moisture) belong to the second. The 'strong' wheats take up most water on baking, and hence yield most loaves. This is the explanation of the apparent paradox; that the larger the *bulk* of a sack of wheat, the smaller is the quantity of bread it is capable of yielding. Another advantage of blending is that the deficiencies of one kind of gluten are made up for by the excesses of another; for gluten is a composite substance, and some

¹ British wheat seldom contains more than 10 per cent. of gluten, while in Eastern Europe and in the Western States of America the proportion may be over 20 per cent. Hungarian wheat is the finest and 'strongest' which the world produces.

wheats are richer in some of its constituents, other wheats in others, and by suitable blending a flour can be produced which is not only 'strong,' but has also a good colour and flavour.

'Seconds' flour yields a bread which is richer in protein than the product of most blends; but the loaf is apt to be rather dark in colour, and on that account not highly appreciated by the public.¹

An analysis has been made by Church² of some of these mill-products of wheat, which brings out the difference in the proportion of protein they contain, to which reference has been made above. The following are the figures:

<i>Protein.</i>				<i>Per cent. N.</i>	<i>Per cent. Fat.</i>
Whole wheat	..	..	..	1'69	2'02
Flour ('patents')	..	..	..	1'62	1'4
" ('seconds')	..	..	..	1'96	1'82
Bran	..	..	..	2'14	2'75
'Fine sharps'	..	..	..	2'60	3'50

It should be added that a considerable proportion of the nitrogen of 'sharps' is not in a protein form.

The following table shows the relative composition of various milling products obtained in America³:

ANALYSES OF WHEAT AND THE PRODUCTS OF ROLLER-MILLING.

	Water.	Protein.	Fat.	Carbohydrates.		Ash.
				Starch, etc.	Crude Fibre.	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Wheat as it enters the mill ..	9'66	14'18	2'61	69'94	1'70	1'91
First break	8'23	14'18	2'68	71'56	1'62	1'73
Sixth break	7'66	16'28	5'34	59'42	5'60	5'68
Bran	10'91	16'28	5'03	56'21	5'98	5'59
Tailings from reduction No. 5	12'12	16'63	3'85	63'93	1'18	2'29
Second germ	8'75	33'25	15'61	35'19	1'75	5'45
Entire-wheat flour	11'4	13'8	1'9	71'0	0'9	1'0
Graham flour	11'3	13'3	2'2	70'5	0'6	1'8
Patent roller process flour:						
Bakers' grade	11'9	13'3	1'5	72'0	0'7	0'6
Family and straight grade	12'8	10'8	1'1	74'6	0'2	0'5
High grade	12'4	11'2	1'0	74'7	0'2	0'5
Low grade	12'0	14'0	1'9	70'4	0'8	0'9

Now, in rejecting the germ and the bran the miller undoubtedly discards some of the most useful chemical constituents of the wheat,

¹ It is very desirable that the semolina, as well as the germ, should be retained in 'seconds' flour. This was done by the old system of stone-milling; but when roller-mills are used most of the semolina goes into the 'patents' flour, and the ordinary 'seconds' is thereby impoverished.

² 'Food Grains of India,' p. 95.

³ United States Department of Agriculture, Division of Chemistry, Bull. 13, pp. 1226-1228, and Office of Experiment Stations, Bull. 28 (rev. ed.), pp. 57, 58.

for with the germ protein and fat are lost, and with the bran mineral matter and the protein contained in its layer of aleurone cells.

The recognition of this waste has led to the devising of two patent processes to prevent it. The first of these deals with the germ (Smith's patent). In this process the separated germ is partially cooked by means of superheated steam. This kills the ferment contained in the soluble proteins, which, as we have seen, acts upon the starch of the flour. The steam also sterilizes the fat of the germ, preventing it from becoming rancid, and so spoiling the taste of the flour. The germ so treated is ground to a fine meal, and of this one part is added to three of ordinary flour, the mixture constituting 'Hovis' flour. It is, as one would expect, much richer in protein and fat than ordinary flour (see table below). Since the discovery of this method of treating the germ, many similar processes have been introduced, and 'germ breads' are now of frequent occurrence in the market. The invention of them marks a decided advance in our methods of bread-making.¹

The second patent process to which reference has been made deals with the bran. It is the 'Frame Food' process. The bran is boiled with water under high pressure, the result of which is to break down most of its cellulose and to extract from it most of its mineral constituents and part of its nitrogen. A proportion of carbohydrate is also removed in a soluble form. The watery extract is filtered and evaporated under diminished pressure to dryness. In this form it constitutes 'Frame Food Extract.' It is rich in mineral matter and nitrogen, although much of the latter is probably not present in a protein form. The extract so prepared forms the basis of various preparations manufactured by the Frame Food Company, to some of which reference will be made later.

The following table shows the comparative composition of the different preparations of wheat of which we have been speaking :

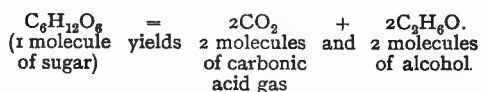
	Wheat-meal.	Medium Flour (House-holds).	Finest Flour (Patents).	Hovis Flour.	Frame Food Extract.
Water	12.1	12.3	13.8	12.2	9.8
Nitrogenous matter ² ..	14.2	10.7	7.9	15.5	16.5
Fat	1.9	1.1	1.4	3.2	1.0
Carbohydrates (including cellulose)	70.6	75.4	76.4	66.8	63.9
Ash	1.2	0.5	0.5	2.3	8.8

¹ A liquid extract of the germ which contains its ferments has recently been introduced under the name of 'Eurissa.' It has much the same uses in bread-making as malt-extracts (see p. 204).
² N x 6.25.

COOKERY OF FLOUR—BREAD.

In order to make flour available as food, it must be cooked in some way or another. The simplest method is to mix the flour with water and bake it. It is in this way that *ship's biscuit* is manufactured. The product, however, is of an almost flinty hardness, and not easy of mastication. Hence the problem early arose, how to cook the flour in such a way that it would be light and easy of digestion. The problem was solved by causing gas to develop in the mixture of flour and water, so converting the latter into a kind of sponge, which was subsequently baked, and into which the digestive juices can easily penetrate. In other words, man learnt to make **bread**. Now, the making of bread from flour is only possible because the latter contains gluten. Gluten is a protein, or mixture of proteins, which has the peculiar property of becoming viscid when mixed with water. If the viscid mass is then blown up with gas, it has sufficient cohesion to remain in the form of a sponge or honeycomb, instead of collapsing again, as it otherwise would do, and allowing the gas to escape. Most other cereals, such as barley, rice, and oatmeal, do not contain gluten, but other forms of protein, which do not become viscid when moistened, and consequently out of these bread cannot be made.

The next question is, How is the gas, which is to be used to blow up the dough, produced? The reply is that the earliest method of producing the gas, and that which is still by far the most widely used, was by **fermentation**. There are certain very minute plants, called yeasts, which are capable of breaking up sugar in such a way as to produce from it carbonic acid gas and alcohol. This process is one of 'fermentation' and may be represented by the following chemical formula :



The yeast is used to manufacture gas out of the sugar contained in the dough. But where does the yeast come from? In the old days—and leaven bread was known to the Egyptians in the time of Moses—it simply came from the air. Yeast cells appear to be floating about in the atmosphere, and when they meet with any soil on which they can grow they start there and produce fermentation. If dough, therefore, be left exposed to the air, yeast cells will ultimately find their way into it, and start to grow and multiply, and produce gas in the dough. But other minute plants, bacteria, get into the dough

at the same time, and these produce acids in it (especially acetic and lactic acids),¹ so that the dough not only ferments, but becomes sour. It was this sour fermenting dough that was first used for making bread. It was called **leaven**. A little of it was added to fresh dough, and the yeast which it contained started to grow with great rapidity through the fresh dough till it was all 'leavened,' and filled with bubbles of gas. Most of this dough was then baked, but a small part was set aside as the 'leaven' to be used in starting fermentation in a fresh batch of bread. The presence of the acids in this leavened bread causes it to have a sour taste, and for this reason the process is now but rarely used. The black sour bread met with in North Germany is still made by a process of leavening.

The next advance upon this process, which must have been introduced after beer was known, was to use pure yeast obtained from the brewer, and thus to get the production of gas in the dough without the development of acids. In more recent years brewer's yeast has been gradually displaced by 'compressed' or 'German' yeast, which is more convenient and keeps better. It consists of pure yeast grown in a special way and purified by repeated washing, after which it is compressed into cakes.

In using yeast to make bread, the first thing the baker has to do is to get his yeast to increase and multiply. This has two advantages: it enables an originally small quantity of yeast to suffice for a whole sack of flour, and it produces a more active yeast, for the young cells are more energetic than those which are older. This stage of bread-making is called the preparation of the **ferment**. About 8 pounds or so of good potatoes are taken and, after being peeled, are boiled down to a thin sort of gruel; 2 pounds of flour are added, and then the yeast and the mixture is stirred up and kept at a temperature of 85° F. or thereabouts. The yeast derives abundant nourishment from the flour, and grows and multiplies very fast. The nitrogenous matter of the flour also acts upon the large starch grains of the potato, converting them in part into sugar, which is straightway attacked by the yeast. After about five hours or so the process comes to a standstill, but the whole ferment is now swarming with young and active yeast cells. A quarter or a third of a sack of flour is now taken and thoroughly mixed with the ferment and some water in a trough. A small quantity of salt—about

¹ For a more complete description of the changes which take place in dough under fermentation, see Weyl's '*Handb. d. Hygiene*,' iii. 247.

$\frac{1}{2}$ ounce for each quartern loaf—is usually, but not always, added. The salt acts as a check on the fermentation. This mixture is spoken of technically as the *sponge*. The young yeast cells now act upon the sugar produced from the flour, and alcohol and carbonic acid gas are liberated all through the sponge. The gas blows the latter up, and after the lapse of about five hours the top breaks and some of the gas escapes. After another hour has elapsed it again breaks, and when this has happened the rest of the sack of flour is added along with some more water. In all about 60 quarts of water are used for every sack of flour. This constitutes the *dough*. It is thoroughly mixed by machinery, and then left for an hour to ‘rise.’ At the end of that time it is weighed and placed in the oven for one and a half hours at a temperature of about 450° F. This treatment causes the gas in the dough to expand and blow the latter up so that it becomes full of little cavities. The heat also hardens and coagulates the proteins of the flour in the outer part of the loaf, where the temperature is highest. Some of the starch is converted into soluble starch and dextrin, and forms the crust. It is to the dextrin that the crust owes its glazed appearance. Altogether about 8 per cent.¹ of the starch in the loaf is thus converted. Some caramel also is formed, and helps to give the crust its flavour and dark colour. When these changes have taken place the dough has passed into the form of bread. Six bushels of wheat go to make a sack of flour (280 pounds), which yields under the above method of treatment about ninety-six quartern loaves. In other words, 1 pound of bread can be obtained from about $\frac{2}{3}$ pound of flour, 33 per cent. of water being taken up in the dough.

It must not be supposed that the method of bread-making is everywhere precisely identical. The above is the process as practised in London, but the details vary somewhat in different localities. Thus, some bakers add the ferment to the whole of the flour right away. Others omit the ferment stage, and begin by making a ‘sponge,’ which is afterwards added to the dough.

Scotch bakers prepare first a ‘barm,’ which is a mixture of malted flour, sugar and hops, and from this make their ‘sponge.’² They also add more salt than is usual here; hence the more marked flavour of Scotch bread.

Now, it will be obvious that any process of making bread by fermentation necessarily implies a certain amount of waste. Some,

¹ Bull. 67, United States Department of Agriculture, 1899.

² See ‘Practical Bread-making,’ by F. T. Vine; London, 1897.

at least, of the starch in the flour is lost by being split up first into sugar, and then into alcohol and carbonic acid gas. The gas is of no use from a nutritive point of view, and the alcohol is mostly driven off by the heat of the oven. It has been calculated by Graham¹ that 300,000 gallons of alcohol are annually lost in this way in the ovens of London alone. A patent was taken out more than fifty years ago for collecting this alcohol, but the process did not pay in practice. A small quantity of this alcohol does remain in the bread, perhaps about 16 grains in each loaf. In a paper in the *Chemical News* (1873) it was computed that forty 2-pound loaves contain as much alcohol as a bottle of ordinary port. Bolas found 0.22 to 0.40 per cent. alcohol in new bread.

Jago² states that in all about 1.3 per cent. of the nutritive ingredients used in bread-making are lost in the course of the operations. Very exact observations on this point have been made in a bakery at Pittsburg. It was found that 1.3 per cent. of the proteins, 71.2 per cent. of the fats, and 3.2 per cent. of the carbohydrates in the ingredients disappeared in the process of baking. The total loss of nutritive material, reckoned in Calories, was about 5 per cent. The very great loss of fat is striking, and has been confirmed by observations made at New Brunswick,³ in which the fat in the original flour had diminished nearly 60 per cent. by the time the bread was completed. It would appear that the fat is volatilized by the heat of the oven.

Fully fifty years ago experiments were made in Glasgow by Dr. Dundas Thomson, which showed that a sack of flour would yield 107 loaves of unfermented bread, and only 100 loaves of fermented bread.⁴

The consideration of this inevitable waste has led to attempts to convert dough into a porous form by other methods than that of fermentation. One of these is the method of Dauglish. In this process the gas is prepared from chemical substances. Water is saturated with it, and is mixed with the flour under pressure in air-tight chambers. The pressure in these is then lowered by opening a trap, and the dough is forced out and blown up by the expanding gas. It is next cut into loaves, and the rest of the baking is quickly completed in the usual way. The product is known as

¹ 'Chemistry of Bread-making,' Cantor Lectures, 1879.

² Jago, 'Science and Art of Bread-making.'

³ Voorhees, United States Department of Agriculture. Office of Experiment Stations, Bull. 53; see also *ibid.*, Bull. 67.

⁴ 'The Food of Animals,' p. 183; London, 1846.

aerated bread. It is quite as porous as that produced by fermentation, but is found by some people to have a rather 'raw' and insipid taste. This is apparently to be attributed to the absence of certain bye-products which yeast produces in the course of its growth. Hence, the bread has not met with universal favour, in spite of its more economical mode of production. The process would appear to be specially suited for the making of wholemeal bread, for it deprives the proteins of the bran of the opportunity of converting some of the starch of the flour into soluble forms, to which soluble substances much of the moistness and heaviness of ordinary wholemeal bread is to be attributed.

Results similar to the above are also obtained by the use of **baking-powders.** These consist of mixtures of various chemical substances, which have this in common, that when moistened the ingredients of the powder act upon one another, carbonic acid being given off. If, therefore, the powder has been thoroughly mixed with the flour, and water be added, the gas will be liberated all through the resulting dough, and the latter will be thoroughly aerated. A *Lancet* Commission, which inquired into the composition of these powders some years ago,¹ reported that the majority of them were pure, consisting of a mixture either of tartaric acid or bitartrate of potash with bicarbonate of soda. A few of them, however, contained alum, and these leave some alumina, or, more probably, hydrated oxide of aluminium, in the bread.² The tartaric acid powders are the most efficient, for they give off twenty-five times their volume of gas; the cream of tartar powders yield only thirteen volumes, and alum powders not more than seven to eleven. In all of these powders the soda is slightly in excess, so that the end reaction of the chemical process is alkaline. There is thus no possibility of their rendering the bread sour. 'Self-raising' flour is flour with which baking-powder has already been mixed.

No matter by what process a loaf is made, it possesses, when finished, certain characters by which bakers judge of its quality. It should be well 'risen,' and possessed of a thin flinty crust, which is neither very light nor very dark in colour, and cracks on breaking. The crumb should be elastic in consistence, of uniform texture without large holes, and of a smooth and silky 'pile.' It should have a sweet, nutty flavour and odour, and in colour should be of a creamy whiteness. Curiously enough, when bakers speak of a loaf

¹ *Lancet*, 1894, i. 562.

² Some also contain considerable quantities of calcium sulphate, which is open to objection on hygienic grounds.

having 'no colour,' they mean that it is rather dark, whereas 'high colour' signifies with them great whiteness. It must be admitted, however, that the above characters, however important æsthetically, are not of much value from a nutritive point of view. Especially is this so in regard to colour. A very white loaf means a loaf in which starch is at a maximum and protein at a minimum, and that is certainly not desirable. For setting up a false standard of whiteness the baker is not to blame. It is the ignorance of the public, which mistrusts a dark loaf.

THE CHEMICAL COMPOSITION OF BREAD.

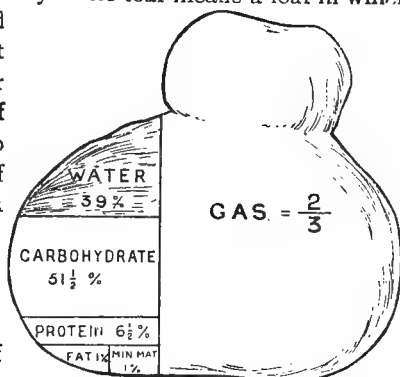


FIG. 17.—DIAGRAMMATIC REPRESENTATION
OF THE COMPOSITION OF A LOAF.

Two-thirds of the volume of a good loaf is made up of gas¹ (Fig. 17), and of the solid part about 40 to 50 per cent. by weight consists of water, so that bread is one of the least watery of vegetable foods, and is relatively much less so than raw meat.² The composition of the dry residue will obviously depend upon that of the flour from which the bread has been made. Especially has one to consider whether the bran and the germ have been left in the flour or not. In white bread these have been excluded. As regards 'brown' breads one cannot speak so definitely, for the term **brown bread** is a vague expression.³ It may simply mean that a certain proportion of bran or of germ or of both have been added to the flour, or it may be applied to bread made from whole wheat meal. In each case the resulting loaf will be 'brown.' Now, bran contains, as we have seen, a good deal of mineral matter and protein. One would naturally expect, therefore, that bread containing bran should be richer in these ingredients than white bread. As regards mineral matter this is certainly true, but it is by no means invariably true of

¹ See Lehmann, *Archiv f. Hygiene*, 1894, xxi. 215.

² The great variability in the amount of water met with in bread renders it desirable that some standard of moisture should be fixed, the exceeding of which should be regarded as an adulteration. In other words, when a consumer pays for a given weight of bread he has a right to expect that his purchase shall contain a definite amount of nutriment.

³ 'Graham flour,' invented by the American physician, Dr. Sylvester Graham, alone contains the entire grain. In making 'entire-wheat flour' the outer and more flinty layers of the bran are removed.

protein. The following table shows in round numbers the mean percentage composition of several white and wholemeal breads analyzed by the writer, and it will be noticed that the protein is

COMPOSITION OF WHOLEMEAL AND WHITE BREAD COMPARED.

					<i>White.</i>	<i>Wholemeal.</i>
Water	..	..	..	..	40.0	45.0
Protein ¹	..	..	..	..	6.5	6.3
Fat	..	..	..	..	1.0	1.2
Starch, sugar and dextrin	..	..	..	..	51.2	44.8
Cellulose	..	..	..	..	0.3	1.5
Mineral matter	..	..	..	..	1.0	1.2

really more abundant in the white bread. These results are confirmed by the following analyses by Atwater:²

				<i>Water.</i>	<i>Protein.</i>	<i>Mineral Matter.</i>
White bread	..	..	..	35.4	9.5	1.1
Brown bread	..	..	..	40.0	5.0	1.9
Graham bread	..	..	..	32.3	8.5	1.5

Bell also says:³ 'Contrary to the views sometimes put forward by the advocates of the use of wheatmeal bread, the samples of household flour submitted to analysis were found richer in nitrogenous matter than the entire wheat grain.' In some recent studies of breads made in America,⁴ the following conclusions were arrived at:

1. Seventeen samples of bread from 'bakers' and 'patents' had 9½ per cent. protein.

2. Bread from imitation whole wheat flour had less protein than the above. That from true wholemeal (*i.e.*, no germ removed) had 1 per cent. more.

It must be added that these breads were apparently considerably drier than ours (32.9 and 33.8 per cent. water respectively). The authors add that no conclusions can be drawn from these figures regarding their nutritive value.

The difference in brown bread is partly due to the amount of water present. The 'protein' of the bran converts some of the starch into dextrin, and this keeps the brown bread moist. In carbohydrates brown bread is decidedly poorer than white. Not only so, but about 2 per cent. of the carbohydrates consists of the comparatively useless cellulose.

¹ N × 5.7. According to Rubner, only 72 per cent. of the nitrogen of bread is in a protein form.

² 'Chemical Composition of American Food Materials.'

³ 'Analysis and Adulteration of Foods.'

⁴ Bull. 67, United States Department of Agriculture (Office of Experiment Stations).

COMPOSITION OF SOME SPECIAL BREADS.

	Water.	Protein.	Mineral Matter.	Carbo-hydrates and Fat.	Characteristics.
'V. V.' bread	40'4	7'5	0'59	51'6	Vis Vitæ is a very good white bread, containing little water, but remaining long moist. It is made of flours rich in protein, and fermented with a specially pure yeast.
Maltina white bread	44'5	5'9	0'7	48'9	A good white bread. Does not contain any malt. Fermented with distiller's yeast.
Nevill's "	37'5	7'2	0'7	54'6	A good white bread, fairly rich in protein.
Triagon "	39'0	6'4	0'7	53'9	An excellent white bread, containing some malted rice and maize flour, and some added phosphoric acid.
(O'Callaghan's)					
Hony white bread	46'8	5'7	0'58	46'8	Kermode's patent. A fancy bread from fine flour, part of the starch of which has been converted by the addition of malt. Not rich in protein. Remains long moist. Contains some maize.
Cyclone wholemeal bread	47'9	7'1	1'4	43'6	A wholemeal bread of average fineness. The meal ground by the cyclone process. About 8 per cent. of it escapes digestion (<i>Goodfellow</i>).
Opmus bread	43'0	6'5	1'3	49'2	A fine wholemeal bread, containing a considerable proportion of germ and little cellulose. Made from Opmus flour (John Thompson and Son's patent).
Seatre's bread	43'4	6'8	1'1	48'7	A brown bread made from Seatre's brown flour, derived from strong British and Duluth wheats, containing malt and germ. Bran very finely ground and outer layer removed. Cellulose amounts to about 2'2 per cent. of the dry constituents. The waste is 8½ per cent. (<i>Goodfellow</i>).
Manhu bread	42'6	7'2	1'3	45'9	A bread made from whole wheat flour of superior quality. Very rich in nitrogen. Cellulose in a state of fine division.
Triticumina bread	43'6	7'3	1'5	47'6	A brown bread made from desiccated wholemeal flour and malted wheat bran in a state of very fine division (Meaby's patent). The dry matter contains about 3½ per cent. of cellulose. About 7½ per cent. of the bread escapes digestion (<i>Goodfellow</i>).
Nevill's wheatmeal	41'5	8'0	1'2	49'3	A moderately fine wholemeal bread, rich in protein.
Maltina brown bread	45'1	7'0	1'9	46'0	A wholemeal malted bread, containing a good deal of rather coarse fibre.
Daren "	46'6	7'9	1'0	44'5	A malted brown bread of good texture, composed of wheat flour, ryemeal and germ. Rich in nitrogen. Cellulose small in amount.
Cytos	42'3	8'1	1'3	48'3	A brown bread composed of wheat flour with a considerable proportion of germ and malt. Cellulose small in amount.
(Marshall and Son's)					
Bernaline brown bread	38'0	8'1	1'9	50'3	A malted brown bread, containing about 10 per cent. of soluble carbohydrates. Comparatively rich in fat. Cellulose small in amount.
(Montgomerie's patent)					
Hovis brown bread	45'0	9'9	1'2	42'3	Richer in nitrogen of all breads. Cellulose small in amount. Ash very rich in phosphoric acid; waste only slightly above that of ordinary white bread (<i>Goodfellow</i>).
Vagos bread	46'0	7'7	1'2	45'1	A malted bread containing a certain proportion of germ. No bran.
'La Nu Lofe'	48'1	6'2	1'2	44'2	A brown bread of excellent texture and taste containing a fair proportion of soluble carbohydrates (9'75 per cent.). It is prepared from a blend of rye and wheat, and is of a high degree of digestibility.
'Veda' bread	24'6	9'4	1'8	63'5	A brown bread containing 53 per cent. of soluble carbohydrates. Very easily digested. Supplied by Bonthron and Co., Glasshouse Street, W.

In analyzing these breads the nitrogen was estimated by Kjeldahl's process, and the protein calculated from it, using the factor 5.7. The ash was determined in the usual way. The carbohydrates were estimated by difference. Only a few fat estimations were made, the fat being usually included in the carbohydrates owing to the small amount of it present, and its unimportance as a nutritive constituent of bread (it may be taken to be usually less than $1\frac{1}{2}$ per cent.). The bread was analyzed in each case on the day after baking.

There are also various **patent and fancy breads** in the market. Of the former the different varieties of **Vienna bread** are a good example. These are made from very fine flour ('patents') fermented with compressed yeast, milk being often added to the dough. The crust is glazed by being subjected to the action of overheated steam before leaving the oven. Of the **patent breads**, the majority are of the 'brown' variety. They are made from flours prepared by various patent processes. Some of them are wholemeal breads, in which the bran has been reduced to varying degrees of fineness; others contain the **germ** in various proportions, of which 'Hovis' is the best-known example. Others, again, are **malted**. The malting of bread consists in adding to it malt-extract, obtained by evaporating an infusion of malted barley to a syrupy consistency at a low temperature. The solid part of the malt-extract so prepared consists mainly of malt-sugar and dextrins. But it also contains the ferment **diastase**, which is able to convert starch into soluble substances (maltose and dextrin). When, therefore, malt-extract is mixed with the dough part of the starch of the latter is ultimately converted into malt-sugar and dextrin. In other words, part of the starch is digested. This has the effect, as already pointed out, of making the bread keep longer moist. Now, it is important to remember that this ferment **diastase** is readily killed if exposed to a high temperature. Hence its activity inevitably ceases as soon as the bread enters the oven. If, then, any considerable part of the starch of the dough is to be converted, the malt-extract must be added very early in the process. As an alternative to that it may be added to a separate part of the flour, and the latter mixed with water and kept at a moderate temperature till most of its starch has been changed, and this mixture added to the dough just before baking. This is the peculiarity of Montgomerie's process, by which 'Bermaline' bread is made. But even under these favourable conditions not much more than 10 per cent. of the carbohydrates of the loaf are in a soluble

form, while in ordinary bread about 4 per cent. is so changed. Seeing, also, that the diastase is killed by the act of baking, it is obvious that malted bread cannot truly be said to *aid* the digestion of other starchy foods. In the preceding table the composition of most of the patent breads is shown from analyses made by the author.¹ The special peculiarities of each kind are also briefly indicated. We shall consider the nutritive and economic value of these breads later. The comparative composition of the crust and crumb of white bread is given by Barral as follows:

	<i>Crust.</i>	<i>Crumb.</i>
Water	17.15	44.45
Insoluble protein	7.30	5.92
Soluble	5.70	0.75
Dextrin and sugar	4.88	3.79
Starch	62.58	43.55
Fatty matters	1.18	0.70
Ash	1.21	0.84

The most striking point about these figures is the much larger proportion of solids in the crust, and the larger amount of soluble proteins and carbohydrates which it contains.

CHANGES WHICH BREAD UNDERGOES ON KEEPING.

When bread is kept it becomes dry from loss of water. The loss, however, is not a very rapid one. The following are the average results of fifty observations by Goodfellow:²

				<i>A 2-lb. Loaf loses</i>	<i>Loss per cent.</i>
In 12 hours	..	..	..	2 oz.	0.9
" 24 "	..	..	..	3 "	2.0
" 36 "	..	..	..	1 3/8 "	5.0
" 48 "	..	..	..	2 1/2 "	8.0
" 60 "	..	..	..	3 1/2 "	11.0
" 72 "	..	..	..	4 1/2 "	14.0

At the end of a week 14 per cent. of the original water is gone, and after a month 18 per cent. (v. Bibra). The bread also becomes stale. The staleness is not entirely due to the loss of water, for, as was long ago shown by Boussingault, one has merely to heat the loaf up again to a temperature of about 300° F. in order to restore much of its freshness. Yet in the course of this rebaking it loses considerably more water than it had already lost by evaporation. The explanation of this rather surprising result is not yet clear. It

¹ In addition to the breads described in the table, mention may be made of 'Turog,' which is a malted brown bread made from flour derived from various cereals, and 'Bananine' bread, which contains banana flour.

² 'Dietetic Value of Bread,' p. 139.

may be that in fresh bread there is some free water present, which becomes united with starch or gluten as the bread grows stale, and that the rebaking sets it free again. That is the explanation of v. Bibra,¹ who has also shown that the freshness will not return if the bread has already lost 30 per cent. of its water. Mattieu Williams,² on the other hand, believes that the staling of bread is due to the shrinkage and coming together of the fibres which form the walls of its visible pores. The water vapour generated by the rebaking drives these fibres apart again. Boutroux³ has still another explanation. He believes that the apparent dryness of stale bread is due to a shifting of moisture from the crumb to the crust. When first taken from the oven the dry crust cools quickly, whilst the moist crumb retains its heat much longer; but as its temperature gradually falls the moisture which it contains tends to distil outwards into the crust. When the loaf is rebaked the moisture is driven back again into the crumb.

The cooking of bread is practically confined to the application of dry heat. This has the effect of driving off water, and of rupturing some of the starch grains, and converting them partly into soluble starch and dextrin. A little caramel also is produced. The result is toast. 'Pulled bread' is made by pulling out the interior of a new loaf and thoroughly baking it. The same changes occur in it as in toast, only to a greater degree.

Biscuits are made from fine flour either alone or with the addition of sugar, butter, milk, flavouring agents, etc. Baking-powder is sometimes added to make them rise a little. They contain very little water (about 5 per cent.), and 3 pounds of them may be taken as equal in nourishment to 5 pounds of bread (Church). The following table shows an analysis of some by Bauer:

COMPOSITION OF BISCUITS.

	Fine Wheaten Biscuits.	Other Wheaten Biscuits.	English Biscuits.
Water	1'18	10'07	7'45
Nitrogenous matter	13'31	11'93	7'18
Fat	3'18	7'47	9'28
Sugar	7'12	36'38	17'02
Other carbohydrates	73'96	32'29	58'08
Cellulose	0'25	0'75	0'16
Mineral matter	1'0	1'14	0'83

¹ V. Bibra, 'Die Getreidearten und das Brot,' Nürnberg, 1860; see also Lehmann, *Archiv f. Hygiene*, 1894, xxi. 215.

² 'Chemistry of Cookery,' p. 209.

³ Cited in 'Bread and the Principles of Bread-Making,' United States Department of Agriculture, Farmers' Bulletin, No. 112, p. 20, 1900.

Rusks may be regarded as a kind of toast. They are made in much the same way as bread, but with the addition of butter, sugar and milk, and are twice passed through the oven, after which they are thoroughly dried.

In the next chapter we shall consider the digestibility and nutritive value of bread.

CHAPTER XII

BREAD (*continued*)—OTHER CEREALS**DIGESTIBILITY AND ABSORPTION OF BREAD.**

THE digestion of bread takes place, in part at least, in the mouth, by the conversion of its starch into dextrins and maltose under the action of the saliva. The more thoroughly bread is chewed and ground into particles, the more complete will the transformation of the starch be. It is on account of the greater ease with which they can be pulverized by the teeth that toast and biscuits are more easily digested than ordinary bread and stale bread than a newly-baked loaf. The dryness of toast and biscuits, too, enables them to become easily saturated with the saliva, and that also greatly facilitates digestion. Further, it must be remembered that a considerable proportion of the starch in biscuits and toast has been already converted into soluble forms in the course of their preparation, so that the labours of the digestive juices in their case are considerably lightened. For these reasons also the crust of bread is more digestible than the crumb, for it is drier, and contains a higher proportion of carbohydrates, owing to the more intense action upon it of the heat of the oven.

The notorious indigestibility of new bread, on the other hand, is due to its moistness, which makes it difficult to chew, and at the same time prevents it from soaking up the saliva.

As regards the **duration of its stay in the stomach**, bread occupies a middle position among the vegetable foods, 70 grammes ($2\frac{1}{2}$ ounces, or an ordinary slice) having completely left the stomach in two hours and twenty minutes, while 150 grammes ($5\frac{1}{2}$ ounces, or two rather thick slices) remain about an hour longer. These periods cannot really be regarded as long when one bears in mind the comparatively large amount of solid matter which bread contains.¹ White bread is

¹ Penzoldt, *Deut. Archiv f. Klin. Med.*, 1893, ii. 535.

disposed of by the stomach rather more quickly than black (e.g., pumpernickel), but there is no appreciable difference in this respect between the behaviour of wholemeal bread and that made from fine flour. The presence of bran in wholemeal bread, however, may act as ballast in the stomach, and give to it the greater 'sustaining' power with which it is commonly credited. Considering the large amount of solid nutriment which they contain, biscuits must be regarded as considerably more digestible than ordinary bread.

New bread, unless very thoroughly chewed, offers greater resistance to the stomach than stale bread, owing to its tendency to form doughy masses.

In the intestine the digestion of the starch and protein of bread is completed, and absorption takes place. On the whole, white bread is very thoroughly absorbed. Even when large quantities are consumed, the loss of nutritive constituents is only about as follows :¹

					Percentage unabsorbed.
Total solids	..	..	..	..	4½
Protein	..	..	..	..	20
Mineral matter	..	..	..	..	25
Carbohydrates	..	..	..	..	3

It will be noted that the greatest share of loss falls to the proteins, of which about one-fifth escapes absorption. This contrasts very strikingly with the case of meat, in which the protein is absorbed almost in its entirety.

The defective absorption of the proteins in bread is apparently due in part to the large amount of starch present;² in part, also, it may be only apparent, and explicable by the fact that bread requires a large production of the digestive juices for its complete solution (see also p. 11).

The above experiments apply to cases in which bread formed the main part of the diet. When given along with other foods, its absorption appears to be considerably increased. Thus, five experiments on an exclusive bread diet showed an average absorption of 82 per cent. of the protein and 99 per cent. of the carbohydrates. When 2 litres (3½ pints) of milk were added to the diet, the absorption of protein rose to 97 per cent., while that of the carbohydrates remained stationary. Ten experiments on milk alone showed a

¹ From the average of a considerable number of experiments by Rubner, Atwater, Zuntz and Magnus-Levy, Goodfellow and others. The quantities consumed were very considerable, amounting to from 600 to 1,000 grammes per day.

² See experiments by Meyer, *Zeit. f. Biolog.*, 1871, vii. 1.

protein absorption of 92 per cent., and an absorption of the carbohydrates to $86\frac{1}{2}$ per cent.¹

This is another instance of the general rule, that a mixture of foods is better absorbed than any one food by itself.

The carbohydrate of bread corresponds to the protein of meat in being almost completely absorbed into the blood. On the other hand, it is rather surprising to find that, of the comparatively small amount of **mineral matter** met with in bread, one-fourth is excreted unabsorbed. Seeing that this is the case, it is surely futile to recommend the use of bread containing a larger amount of mineral constituents.

Brown and wholemeal breads differ from white bread, as we have already seen, in containing more or less of the bran of the wheat.² Any difference which they show in absorbability, therefore, when compared with white bread, will depend probably on this peculiarity.

Now, bran contains a large amount of cellulose, some analysts placing the proportion as high as 20 per cent. or more.³ Not only so: the cellulose of bran is in a dense and woody form. It has already been pointed out that, at the best, cellulose is but imperfectly digested by man, and that when it becomes woody it is hardly digested at all. Hence one would expect the constituents of bran, enclosed as they are by woody cellulose, to be but indifferently absorbed. Experiment fully justifies this expectation. Donders⁴ observed that the walls of bran cells were digested by herbivora, but not by man; and Giraud was able to demonstrate the aleurone cells in the human excreta unchanged—an observation which has been more recently confirmed by Moeller.⁵ Pozziale,⁶ too, found that bran, which had originally contained 13 per cent. of nitrogenous matter, still retained fully $3\frac{1}{2}$ per cent. after traversing successively the digestive apparatus of two dogs and a hen. One is therefore not surprised to learn that Rubner⁷ found that only one-third of the nutriment contained in bran is capable of being made use of by the human digestive organs.

¹ Bull. 53, United States Department of Agriculture, Office of Experiment Stations, p. 43.

² Ordinary bread is made from flour which represents 70 per cent. of the wheat grain, the remainder being used for offals. Standard bread is made from 80 per cent. flour, and in wholemeal breads an even higher degree of extraction is employed.

³ Lebbin, *Archiv f. Hygiene*, 1897, xxviii. 212.

⁴ Quoted by Meyer, *op. cit.*

⁵ *Zeit. f. Biolog.*, 1897, xxxv. 291. This writer gives an exhaustive summary of the results of previous workers upon the digestion of various cells as tested by microscopical examination of the stools.

⁶ Quoted by Meyer, *op. cit.*

⁷ *Zeit. f. Biolog.*, 1883, xix. 45.

Seeing that, of the total amount of mineral matter which wholemeal bread contains, fully 65 per cent. belongs to the bran, one would expect the mineral constituents of such bread to be specially singled out for defective absorption.¹ And this is so. Fully half of them never enter the blood at all (Rubner, Goodfellow, and others). The carbohydrates, too, of wholemeal bread are not so completely absorbed as those of white bread, more than 5 per cent. being lost.² Some observers, indeed, have found a greater difference between the absorption of wholemeal and white bread in respect of this constituent than in regard to any other.

The results of observations on the absorption of the *proteins* of wholemeal bread are by no means unanimous. Some experimenters (*e.g.*, Goodfellow) have found but little difference between the behaviour of wholemeal and white bread in this respect, while others (*e.g.*, Meyer), comparing whole wheat bread with moderately fine rye bread, have found a difference of 10 per cent. or more in favour of the latter.

Some of the most conclusive experiments on this point may be cited here. Rubner³ compared the relative absorption of bread made from the three following flours: (1) Finest white flour ('patents'); (2) middle quality ('seconds'); (3) 'wheatmeal flour.'

In making the loaves, the directions of the Bread Reform League were followed. Upwards of 600 grammes of the bread were eaten daily, the amount of nutrients contained in each case being as follows:

	Nitrogen.	Fat.	Carbo- hydrates.	Mineral Matter.
No. 1.	10.20	6.69	528.8	2.39
" 2.	13.19	5.65	507.9	2.85
" 3.	12.45	12.65	504.5	8.54

Bread No. 1 contained 68.5 per cent. water; No. 2 had 69.4 per cent.; No. 3, 62.4 per cent. The *percentages of loss* from non-absorption were these:

Bread.	Quantity of Dry Substance eaten.	Percent. Dry Substance lost.	Percent. N lost.	Percent. Fat lost.	Percent. Carbo- hydrate lost.	Percent. Ash lost.
No. 1.	615.3 grammes	4.03	20.07	44.69	1.10	19.28
" 2.	612.6 "	6.66	24.56	62.83	2.57	30.35
" 3.	617.1 "	12.23	30.47	51.14	7.37	44.98

¹ There is some reason to believe, however, that wholemeal bread is capable of yielding a larger amount of iron to the body than white bread. (See United States Department of Agriculture, Bulletin 185.)

² Moeller, however (*Zeit. f. Biolog.*, 1897, xxxv. 291), states that he could find no starch cells in the fæces, even when Graham bread was eaten. Notwithstanding this, he decides the question of wholemeal versus white bread entirely in favour of the latter.

³ *Zeit. f. Biolog.*, 1883, xix 45.

The *absolute* losses were:

	Fresh Fæces.	Dried.	N.	Fat.	Carbo- hydrates.	Ash.
No 1.	132.7	24.8	2.17	2.99	5.83	2.39
" 2.	252.8	40.8	3.24	3.55	13.10	3.90
" 3.	317.8	75.7	3.80	6.47	37.23	8.34

He draws special attention to the great absolute loss of carbo-hydrate in the wholemeal bread.

Other experiments have been made in America,¹ in which the absorption of bread made from 'patents' and 'bakers' flour respectively was studied, 672 grammes (24 ounces) of bread being taken daily. The results were:

Bread.	PER CENT. DIGESTED.			
	Dry Matter.	Protein.	Fat.	Carbo- hyd. ates.
'Bakers'	94.2	91.0	94.6	96.8
'Patents'	94.4	90.5	94.7	96.9

No difference was found in this case between the two kinds of bread. In another set of experiments,² white bread, entire wheat, and Graham bread were compared, with the following results:

100 GRAMMES OF BREAD YIELD IN THE BODY.

	Calories.	Protein.
White bread	269	8.6 grammes.
Entire wheat bread	235	8.6 "
Graham bread	218	8.3 "

Taking the results as a whole, it may fairly be concluded that the protein of wholemeal bread is not so well absorbed as that of white bread. Even bread made from decorticated wheat does not offer the advantages often ascribed to it, for exact experiment has shown that it is not much better absorbed than ordinary wholemeal bread.³

The defective absorption of wholemeal bread is no doubt to be attributed to the large amount of cellulose which it contains. The cellulose acts chiefly by preventing the access of the digestive juices to the nutritive ingredients which are enclosed in it. It is also sometimes said to interfere with absorption by hurrying on the contents of the intestine by the stimulating influence which it exerts on peristalsis. This would appear, however, to be an error, for Rubner found⁴ that, on the whole, the fæces on a coarse bread diet

¹ United States Department of Agriculture, Office of Experiment Stations, Bulletins 67, 101, 126.

² United States Department of Agriculture, Farmers' Bull. 112. See also Bulls. 85 and 101, Office of Experiment Stations, 1900 and 1901, p. 35, 1900, of the same Department.

³ Menicanti and Prausnitz, 'Untersuchungen über das Verhalten verschiedener Brotsorten im Menschlichen Organismus' (*Zeit. f. Biolog.*, 1894, xxx. 328).

⁴ *Op. cit.*

were more slowly evacuated than those of fine bread. On the other hand, the residue of wholemeal bread seems more prone to undergo fermentation, with the production of acids, and it is to this that the greater wateriness of the wholemeal bread faeces is to be attributed, for the intestine endeavours to neutralize the acids by a greater flow of alkaline fluid. It is probably for this reason that wholemeal bread interferes somewhat with the absorption of other foods. Thus, Goodfellow¹ has found that the waste in milk is greater by 3 per cent. when given along with wholemeal bread than when taken alone. This, as we have seen, is the very reverse of the effect exercised by ordinary bread.

Taking the mean results of available experiments, one may contrast the absorption of the constituents of white and wholemeal bread thus:²

	White Bread.			Wholemeal Bread.			
Total solids	4½ per cent.	14	per cent.		} lost.
Proteins	20	20 to 30	..		
Ash	25	51	..		
Carbohydrates	3	6	..		

It might reasonably be contended that the defective absorption of the constituents of bran is due to imperfect grinding, and that if the bran were reduced to as fine a powder as the flour it would be as well digested as the latter. To some extent this is true, and brown breads made from finely ground patent wholemeals are unquestionably better digested than the ordinary coarse brown bread. Observations by Romberg,³ however, on the digestion of rye bread, show that, no matter how well ground the bran is, it is never as well absorbed as the flour. He prepared a series of breads from rye, the meal used being in each case of equal *fineness*, but differing in the proportion of bran contained. Thus, bread No. 1

¹ 'Dietetic Value of Bread,' p. 199. In this work will be found numerous experiments on the absorption of wholemeal bread.

² During the war an extensive series of experiments was instituted by the Food (War) Committee of the Royal Society on the digestibility of different breads by human beings, which yielded results much more favourable to the coarser breads than the earlier observations cited above would lead one to expect. Thus they found that during the use of 80 per cent. bread there was extracted for the purposes of nutrition 96·14 per cent. of the energy contained in the diet, and when 90 per cent. bread was taken, 94·5 per cent. was extracted. Even the addition of 20 per cent. coarsely dressed maize flour did not affect adversely the digestibility of the bread. Spriggs and Weir (*Lancet*, November 10, 1917) obtained similar results.

³ Romberg, *Archiv f. Hygiene*, 1897, xxviii. 244.

consisted of the flour only and was perfectly white, while No. 4 was made from the whole grain and was very dark; Nos. 2 and 3 were of intermediate quality. The following tables show (1) the composition of the *meals* used; and (2) the percentages of *waste* in the digestion of the corresponding breads:

(1)		In Dry Substance.			
No.	Water.	Protein.	Fat.	Ash.	Carbohydrate.
No. 1.	11'25	7'43	0'09	0'49	91'09
" 2.	11'84	11'59	1'14	0'92	86'35
" 3.	11'26	17'28	2'13	1'89	78'70
" 4.	11'40	16'84	2'13	2'22	78'81

(2)		Dry Substance.	Protein.	Ash.	Carbo- hydrates, etc.
No. 1.	4'15	22'0	58'8	1'66	
" 2.	7'51	28'6	75'5	4'15	
" 3.	13'64	30'5	74'4	8'08	
" 4.	20'07	43'0	61'9	14'40	

Seeing that the ingredients of the bread were in an equally fine state of division in every case, the author concludes that even bran *flour* is not suitable for human food, and that no method of preparing it will make it as capable of being absorbed as white flour.

Whether finely-ground wholemeal bread yields more **mineral constituents** (especially phosphates) to the body than white bread has not been definitely settled by experiments, although from the observations of Rubner already cited, the *absolute* yield of mineral matter would seem to be greater in the case of wholemeal bread. Sherman¹ states that the body probably absorbs from a pound of genuine whole-wheat bread at least twice as much phosphorus, iron, and calcium compounds as from a pound of white bread. Seeing, however, that an ordinary mixed diet always contains an excess of phosphates, there is usually nothing to be gained by increasing the amount of these ingested. In any case a large proportion of the phosphates in ordinary bread are present in organic combination, and are therefore more available for nutrition than the mineral phosphates of the bran. On the other hand, where bread forms the chief constituent of the diet, the use of a *finely-ground* wholemeal bread is advantageous from the mineral point of view.

The absorption of wholemeal bread has been dwelt upon at considerable length, for reasons that will be apparent when we come to consider its nutritive value. As regards the digestibility and absorption of bread in general, it only remains to be added that there is some reason to suppose that custom plays a considerable part in it, and that people who are habitually large bread-eaters

¹ 'Food Products' (New York: The Macmillan Co., 1914), p. 293.

acquire the power of digesting it more completely than those who are not so habituated to its use.¹

NUTRITIVE VALUE OF BREAD.

Weight for weight, though not bulk for bulk, bread must be regarded as one of the most nutritious of our ordinary foods. This is due largely to the fact that three-fifths of it consist of solid nutriment, and but two-fifths of water, and there is no animal food and but few *cooked* vegetable foods of which the same can be said.

Of the chemical constituents necessary for proper nutrition, bread yields to the blood a large proportion of carbohydrates, a moderate amount of protein and mineral matters, but almost no fat. The fact that bread is usually eaten with butter, however, renders the absence of fat a consideration of but little importance.

Yet bread cannot be regarded as a perfect food. The proportion of protein to carbohydrate is too low. An ideal food would contain one part of protein to 4·2 parts of carbohydrate, whereas in white bread the proportion is only 1 to 8½. In order to obtain from bread the protein requisite in an ordinary diet, a whole 4-pound loaf must be eaten every day, and that would contain more than twice as much carbohydrate as one really requires. To the ordinary mixed feeder this does not matter, for he supplements the deficiency of protein by adding to the bread a 'protein-carrier' such as meat, milk, or cheese. Where bread forms the staple article of diet, however, as it does in many poor households, this **lack of protein** must be regarded as a serious drawback. Various methods of overcoming it have been tried, all of which consist in adding to the flour some other highly nitrogenous substance. **Peasmeal** has been used with this object, and when added to flour in equal proportions is said to make a good loaf. **Skim milk** has also been employed. A loaf made entirely with skim milk had the following composition when compared with a loaf made from the same flour and water:²

					<i>Milk Loaf.</i>	<i>Water Loaf.</i>
Water	..	..	..	..	31·29	32·59
Protein	..	..	..	..	9·73	8·75
Carbohydrate	..	..	..	..	56·66	56·65
Fat	..	..	..	..	0·96	0·86
Ash	..	..	..	..	1·39	1·15

Meat has also been proposed as an addition, 2 pounds of flour

¹ See Rubner, *Zeit. f. Biolog.*, 1879, xv. 154.

² Sartori, quoted by Stutzer, Weyl's 'Handbuch der Hygiene,' iii. 251. Some American analyses ('The Digestibility and Nutritive Value of Bread,' Bull. 85, United States Department of Agriculture, Office of Experiment Stations, 1900) also showed that the chief difference between bread made with skim milk and ordinary bread is that the former contains 1 per cent more protein in the fresh substance than the latter.

and 1 pound of cooked minced meat making a good and digestible loaf, which, with the addition of fat, is almost a complete food.

More elaborate methods are by the addition of **Aleuronat** or of **casein**. Aleuronat was introduced by Dr. Hundhausen. It is simply gluten prepared in a special way, and contains 80 per cent. of protein. It is a colourless, odourless powder, which is well digested and absorbed, and when added to flour in the proportion of 1 part to 3 yields a loaf containing nearly 20 per cent. of protein, at a cost but little above that of ordinary bread.¹ The addition of casein is employed by the Protene Company in their household Protene bread, 25 per cent. of casein being added to ordinary flour. The resulting loaf is very rich in protein, but, owing to the price of casein, is necessarily rather expensive.

It must be admitted that none of these methods of increasing the amount of protein in bread is altogether adapted for ordinary use, and that they are all apt to make the cost of the bread too great. Perhaps one or other of the **germ breads** now in the market, of which Hovis is the best example, meets the requirements better than any substitute which has yet been proposed. About 3 pounds of such a bread would supply all the protein required daily, and would only contain a slight excess of carbohydrate. With the free addition of butter or some other fat, it is not far from being a complete food. Unfortunately, there are not many experiments available to determine whether or not the 'germ' is well absorbed. Goodfellow² has given some attention to the matter, however, in the case of Hovis bread, and found that the loss was only very slightly above that of ordinary white bread.

Putting aside such patent breads, it may be said that white bread made from 'seconds' flour will yield more nitrogen to the body than a bread made of ordinary flour, and still more than one made of 'patents.' The reasons for this have already been discussed (p. 193).

When we pass on to consider the **relative nutritive values of white and wholemeal bread**, we are on ground which has been the scene of many a controversy. It is often contended that wholemeal is preferable to white bread, because it is richer in protein and mineral matter, and so makes a better-balanced diet. But our examination of the chemical composition of wholemeal bread has shown that, as regards protein at least, this is not always true, and even were it the case, the lesser absorption of wholemeal bread, which we have seen to occur, would tend to annul the advantage. As regards mineral

¹ Carl Voit, *Archiv f. Hygiene*, 1893, xvii. 408.

² 'Dietetic Value of Bread,' p. 255.

matter the evidence is not so clear, and there is some reason to believe that the absolute yield of these constituents to the body is greater with wholemeal bread, especially if it be finely ground. Wholemeal bread is also richer in vitamins. In the case of an individual living upon an ordinary mixed diet, however, these advantages are not a matter of great importance.

Where bread constitutes the chief source of nutriment, as is unfortunately only too often the case, it is probably wisest to use the old-fashioned household bread, made from 80 per cent. or so-called 'standard' flour, which is not brown but cream-coloured, and which includes both the germ and semolina. This is certainly superior to ordinary white bread from a chemical point of view, whilst it is in no way inferior to the latter in digestibility and capability of absorption.¹

ECONOMIC VALUE OF BREAD.

Bread is not only one of the most nutritious, but it is also amongst the cheapest of foods. In an earlier chapter we saw that for a given sum one obtains a larger number of Calories from bread than from any other food. As regards the actual amount of dry nutriment obtained, bread also heads the list. Thus a penny-worth of—

Bread yields	..	..	8 oz.	Cheese yields	..	..	2½ oz.
Oatmeal	..	..	7½ "	Carrots	..	..	2 "
Lentils	..	..	5½ "	Fish	..	..	1 "
Potatoes	..	..	5½ "	Meat	..	..	0½ "
Rice	..	..	5½ "				(Goodfellow.)

Taking protein alone as the standard, it is found that bread is a fairly cheap source even of that constituent. Thus—

1 pound of protein costs in the form of—

Maize 6d.	Bread .. 1s. 2d.	Beef:
Beans 7d.	Cheese .. 1s. 3½d.	Cheapest .. 1s. 4½d.
Oatmeal 7½d.	Rice 1s. 5d.	Best .. 4s. 5d.
Flour 11d.	Milk 2s. 2½d.	Eggs 5s. 0½d.

¹ For a very full discussion of the whole subject, the conclusions of which are in substantial agreement with the views set out above, see Dr. J. M. Hamill's 'Report to the Local Government Board on the Nutritive Value of Bread made from Different Varieties of Wheat Flour,' 1911. A paper by M. Hindbode ('Untersuchungen über die Verdaulichkeit Einiger Brotsorten,' *Zeitsch. f. Physik. und Diät. Therapie*, xvii. 1913, p. 68) may also be consulted, and the Report by the Food (War) Committee of the Royal Society on the Digestibility of Breads. Experiments made by the 'Umanitaria' of Milan on workmen on normal diets, except with respect to the character of their bread which was respectively of 75, 80, or 85 per cent. milling or 'complete' flour, showed that maximal economy is effected with 80 per cent. flour. Above that the added constituents decrease absorption to the point at which actual wastage occurs (translation in *Rev. Gen. des Sciences*, November 15, 1915, p. 612).

Of the patent and fancy breads as a whole, it may be said that they are relatively somewhat dearer than white bread. About $1\frac{1}{2}$ d. per pound may be regarded as their average cost. Even ordinary brown bread has ceased to be cheaper than white, and cannot therefore be recommended on that ground.

I may conclude this subject in the words of Dr. Goodfellow:¹ 'It will be perfectly clear . . . that bread is one of the cheapest foods, not only with regard to the actual weight of nourishment obtained, but also with regard to the variety of the nutrient constituents; and the purchaser who expends his modest $2\frac{1}{2}$ d. on a 2-pound loaf may rest assured that he could not spend his money to better advantage, except, perhaps, in the purchase of oatmeal, which contains slightly more energizing nutriment than bread.'

Bread has been dwelt upon at some length on account of its great practical value. The other food-stuffs derived from wheat may be dismissed more briefly.

Semolina is prepared from the central part of hard wheats which are rich in gluten, and is largely used in the South of Europe. It contains about 11 per cent. of protein, or half the amount contained in an equal weight of beef. It must thus be regarded as a fairly nitrogenous vegetable food, and is useful for making puddings, porridge, thickening of soups, etc.

Macaroni, vermicelli and the Italian pastes are also made from flours rich in gluten. The flour is made into a paste with water, and the viscosity of the gluten then allows it to be moulded in various ways or drawn into tubes. It is afterwards dried or slightly baked.

Macaroni and vermicelli absorb about three times their weight of water in the process of cooking, so that the product when eaten, although highly nutritious, is about eight times poorer in nitrogen than a similar weight of beef.

Macaroni and vermicelli are absorbed almost in their entirety.² Their use is therefore indicated in conditions where it is advisable to leave behind as small a residue as possible in the intestine.

The following table represents the composition of these and some similar preparations from analyses by Balland:

¹ 'Dietetic Value of Bread,' p. 106.

² Rubner, *Zeit. f. Biolog.*, 1879, xv. 165

COMPOSITION OF ITALIAN PASTES, Etc.¹

	Water.	N Substances.	Fat.	Starch, etc.	Cellu- lose.	Ash
Macaroni (1895) ..	11.60	10.98	0.45	76.05	0.28	0.64
" (1897) ..	12.00	10.89	0.65	75.70	0.26	0.50
Vermicelli (1896) ..	10.90	11.74	0.50	75.74	0.38	0.74
" (1897) ..	10.00	12.51	0.80	75.51	0.28	0.90
Pâtes d'Italie (1897) ..	10.40	12.51	0.80	75.23	0.30	0.76
Semolina (1895) ..	9.20	13.50	0.85	75.45	0.50	0.50
" (1896) ..	9.20	10.42	0.55	78.63	0.45	0.75
" (1897) ..	10.50	11.96	0.60	75.79	0.50	0.65
Rice semolina (1898) ..	10.80	7.34	0.30	80.96	0.40	0.20
Foreign tapioca (1897)	12.80	0.00	0.20	86.88	0.08	0.04
French potato tapioca (1897) ..	16.00	0.45	0.15	82.95	0.00	0.45

The following are some patent preparations of wheat :

Granuto² is a wheat product which has been thoroughly cooked and subjected to the action of malt sufficiently to convert a considerable proportion of its starch into dextrin and maltose.

Granola is a whole-wheat preparation manufactured by Mr. James Marshall in this country.³ The same maker produces a granular preparation of the endosperm of wheat under the name of **Farola**.

Florador is another wheat product of recent introduction, and in a granular form. It contains 10.6 of protein and 0.3 per cent. of mineral matter, and is recommended for use in the making of blancmange, etc. It is undoubtedly far more nutritious than such preparations as cornflour, which are so commonly used for a similar purpose.

The composition of some of the above preparations, when cooked with water in the usual way, is as follows :⁴

	Water.	Protein.	Fat.	Starch.	Cellulose.	Mineral Matter.
Semolina	90.17	1.93	0.08	7.25	0.04	0.13
Vermicelli	87.14	2.44	0.01	10.82	0.07	0.13
Hominy	86.63	2.81	0.09	9.87	0.16	0.02
Farola (fine grain) ..	90.24	1.84	0.02	7.83	0.06	0.06
" (medium grain) ..	89.15	1.91	0.01	8.89	0.06	0.14
" (large grain) ..	86.08	2.39	0.01	11.06	0.15	0.07
Florador	89.45	1.80	0.01	8.67	0.08	0.10
Granola	67.40	2.52	0.03	9.42	0.10	0.18

¹ Balland, *Journ. de Pharm. et de Chim.*, 1898, 6^{me} sér., vii. 328; *Analyst*, 1898, p. 178.

² Battle Creek Sanitarium Company, Ltd., Michigan, U.S.A. Several other ingenious and useful cereal preparations are made by this company.

³ 25, East Cumberland Street, Glasgow.

⁴ Analyses by Katherine I. Williams (*Journ. Amer. Chem. Soc.*, 1907, xxix., No. 4).

Shredded wheat is a preparation of whole wheat in the form of shreds or flakes, which have been cooked to the consistence of a biscuit, and represents the whole grain in a very digestible form. **Chapman's whole-wheat flour** is described at p. 469.

Force consists of malted whole wheat in the form of flakes, cooked with steam. It is easily digested, but not really of higher nutritive value than fine wheaten biscuits (see p. 207). The following is its composition :

Water	..	..	..	..	..	9.28 per cent.
Protein	..	..	..	..	..	9.42 "
Soluble carbohydrates	..	..	..	..	..	11.36 "
Insoluble	..	..	..	..	..	65.69 "
Fat	..	..	..	..	..	1.35 "
Mineral matter	..	..	..	..	..	2.90 "

Grape-Nuts is another malted preparation of the entire wheat berry, which requires no cooking. It contains a high proportion of soluble carbohydrates, as well as a considerable amount of protein, as is shown by the following analysis :

Water	..	..	..	..	..	6.18 per cent.
Protein	..	..	..	..	..	11.97 "
Soluble carbohydrates	..	..	..	..	..	42.72 "
Insoluble	..	..	..	..	..	36.52 "
Fat	..	..	..	..	..	0.61 "
Mineral matter	..	..	..	..	..	2.00 "

Roborat and **Glidine** are protein preparations derived from wheat. In addition, they contain an appreciable amount of lecithin. As they are practically free from starch they are useful aids in the preparation of diabetic foods, and may be regarded as having much the same nutritive value and uses in the diet as casein preparations.

OTHER CEREALS. OATS.

Oats may be regarded as the most nutritious of all cereals. They are rich in nitrogenous matter and mineral substances, and are peculiarly rich in fat, the only other cereal which can at all compare with them in that respect being maize. Starch is present to the extent of about 38 per cent. Further, of the total nitrogenous matter, 94 per cent. is in the form of protein, and therefore available for tissue-building. Unfortunately, the husk of oats is closely adherent, and cannot be entirely separated from the kernel, so that

by the ordinary methods of grinding a good deal of cellulose is left in the meal in the form of small sharp particles. These act as stimulants to the intestine, and make oatmeal a valuable food where the intestinal movements are sluggish, but, on the other hand, are apt to prove rather irritating to some persons.

Oatmeal is also found to be a 'heating' food in the case of some individuals, and the development of skin eruptions sometimes follows its use. This 'heating' effect is said not to be due to the large amount of protein which it contains, but to a special constituent to which the name 'avenin' has been given.¹ Similar 'stimulating' results are often observed in horses which are liberally supplied with oats. It must be stated, however, that the existence of this substance is denied by many observers. Oatmeal is also one of the few vegetable foods which contain appreciable quantities of uric-acid formers (purin bodies). It is therefore well to forbid its use in some cases of gout. There are various ways of preparing oats for human food. It may be simply cleaned and ground, the result being oatmeal of various degrees of fineness, or the branny particles may be separated, and the 'oat flour' alone used. Groats consist of oats from which the husk has been entirely removed; when crushed, Embden groats results.

Rolling has recently begun to be employed as a method of preparing oats, instead of grinding. The great pressure to which the grains are subjected between the rollers ruptures the cell walls, breaks down the cellulose, and flattens the grains out so that they are more easily softened by cooking. By the application of heat during the rolling process, the grains are at the same time partially cooked. This not only has the advantage of rendering subsequent preparation for the table considerably less laborious, but also alters the fat, which is so abundantly present in oats, in such a way that it is less liable to become rancid, so preserving the natural flavour of the grain.

'Quaker Oats' is one of the best known of these preparations. 'Waverley Oats,' 'Provost Oats,' Carr's 'Oaten,' 'Creamota,' and Montgomerie's 'Berina' are examples of Scottish rolled oats. 'Avenine' is a similar product. The composition of some special preparations of oats is shown in the following table:

¹ Sanson, *Comptes Rendus*, 1883, xcvi. 75.

PREPARATIONS OF OATS.

	Scottish Oatmeal.	Irish Oatmeal.	'Quaker Oats.'	Carter's Oats.	'H.O.'	Mont- gomerie's Fine Oatmeal.	Scott's Oat Flour.	Robin- son's Groats.
Water ..	5.0	5.0	7.8	3.1	9.0	6.3	5.8	10.4
Protein	14.6	13.4	14.7	12.9	13.8	11.0	10.0	11.3
Fat ..	10.1	8.8	6.2	6.2	8.3	6.8	5.0	6.5
Carbo- hydrates	65.1	68.4	69.8	76.0	67.2	74.2	77.9	70.4
Cellulose	3.1	1.7						
Mineral matter	2.1	2.0	1.5	1.8	1.7	1.7	1.3	1.7

The composition of some of these, when prepared ready for eating, is as follows:

COMPOSITION OF ROLLED OATS WHEN COOKED.¹

	Water.	Protein.	Fat.	Starch.	Cellulose.	Mineral Matter.
Quaker Oats	92.48	1.65	0.32	6.24	0.09	0.24
Provost Oats	88.44	2.00	0.36	9.00	0.16	0.24
Mother's Oats	89.72	1.92	0.45	8.70	0.15	0.18

It will be observed that the finer the product the poorer it is in nitrogenous and mineral matters. In this respect oat flour bears the same relation to oatmeal as fine wheat flour does to whole wheatmeal.²

Veda Oatmeal³ is a special preparation of oats in which much of the starch has been converted into soluble forms. It is thus more easily digested than ordinary oatmeal, and may agree with patients in whom the latter causes acidity. **Plasmon Oatmeal** is a combination of plasmon and oatmeal, which contains 20 per cent. of protein and 8 per cent. of fat. It is pre-cooked, and of very high nutritive value.

Owing to the absence of gluten, oatmeal is unfitted for bread-making, and is usually simply mixed with water and made into cakes. By mixing fine oatmeal with an equal quantity of wheat flour, however, a fairly good loaf can be obtained. A given weight of oatcake (made without butter) contains rather more than twice as

¹ Analyses by Katherine I. Williams (*Journ. Amer. Chem. Soc.*, 1907, xxix., No. 4).

² Cowan's 'special quality' of Scotch oat flour is an excellent preparation for the making of gruels and as a food for children.

³ The Veda Food Company, 25, North Bridge, Edinburgh.

much building material as an equal quantity of bread, and has almost twice as great a fuel value.

Oatmeal requires to be very thoroughly boiled in order to soften the cellulose which it contains. 'Brose,' which is made by merely stirring oatmeal into boiling water, is not a food for delicate stomachs. As regards the absorbability of oats, experiments show¹ that porridge made from rolled oats, even if taken in considerable quantities, is very well absorbed. Roughly speaking, 95 per cent. of its protein, 93 per cent. of its fat, and 96 per cent. of its carbohydrates enter the blood, whilst 92 per cent. of the energy which it contains is 'available' in the body. This compares very favourably with the results yielded by bread. On purely chemical grounds, oats compare very favourably with wheat as a source of nutriment. A typical tea and bread-and-butter meal (No. 1) may be contrasted with one of porridge and milk (No. 2) of the same cost (1½d.) thus²:

		No. 1.		
<i>Ingredients.</i>		<i>Protein.</i>	<i>Fat.</i>	<i>Carbohydrates.</i>
Tea .. ..	..	—	—	—
Sugar (½ ounce) ..	..	—	—	14·2
Milk (1½ ounces) ..	..	1·2	1·4	1·7
Bread (10 ounces) ..	..	26·1	3·7	150·8
Butter (½ ounce) ..	..	0·2	11·5	—
Total .. ..	..	27·5	16·6	166·7
		No. 2.		
Oatmeal (8 ounces) ..	..	36·6	16·4	153·4
Milk (10 ounces) ..	..	9·4	11·3	14·2
Total .. ..	..	46·0	27·7	167·6

The total energy value of the first meal is 950·6 Calories ; of the second, 1,133 Calories. The superiority of the porridge and milk meal as a source both of building material and of energy is very striking.

MAIZE (INDIAN CORN).³

Maize is not so largely used as human food in Great Britain as it should be, but throughout America it forms a staple article of diet, while in Mexico and Natal maize is literally the 'staff of life' (Letheby). It was introduced into Ireland at the time of the potato famine in 1848, and has since established a place for itself in the

¹ Bulletin No. 101, United States Department of Agriculture, Office of Experiment Stations, p. 47, 1901.

² 'A Study of the Diet of the Labouring Classes in Edinburgh,' p. 77 (Edinburgh : Otto Schulze and Co.).

³ For much practical information on the use of maize as a food, see United States Department of Agriculture's Farmers' Bulletins, Nos. 559 and 565 (1913 and 1914).

dietary of the people, so that Ireland now imports more of it for food purposes than any other European country.

Chemical analysis shows that maize is quite as nutritious as wheat in all except its mineral ingredients, while it is richer in fat than any cereal except oats, containing twice as much of this important constituent as wheat or barley, and three times as much as rye. In nitrogenous matter it is slightly inferior to most other cereals, but fully 87 per cent. of this is in a protein form. As regards its digestible carbohydrates, it is equal to wheat, but somewhat inferior to barley or rye. The following table shows the average composition of maize products :¹

	Protein.	Fat.	Starch, Sugar, etc.	Fibre	Ash.	Water.	E. V. per lb.
Whole maizemeal, unbolted ..	8·7	4·7	71·1	2·2	1·3	12·0	1,850
Whole maizemeal, bolted ..	8·9	4·9	72·0	1·2	1·0	12·0	1,765
Maizemeal, granulated (semolina)	9·2	1·9	74·4	1·0	1·0	12·5	1,770
Maize flour	7·1	1·3	77·5	0·9	0·6	12·6	1,645
Cornflour (corn starch) ..	—	—	90·0	—	—	—	1,675
Flaked maize	9·3	3·48	2·43	1·77	1·18	11·84	1,663

Maize is prepared for food in many different ways. In Ireland it is made into a sort of porridge, called *stirabout*, or, in the more expressive phraseology of America, *mush*. In Northern Italy and the South Tyrol it is prepared in a similar way, but with the addition of cheese and other ingredients. Maizemeal is prepared by grinding after removal of the germ and husk. A yellow and a white meal are thus prepared, but there is no difference between them as far as nutritive value is concerned. Fine maizemeal is more gritty than wheat flour, but when mixed with the latter its presence can hardly be detected. The comparative cheapness of maize flour is an inducement to millers to adulterate wheat flour with it, and this is already being done to some extent in America and France. Flour so adulterated yields fewer loaves than an equal quantity of pure wheat flour, and the bread produced is moister than wheaten bread, and has a tendency to be sodden. An addition of 10 per cent. of maize flour is calculated to mean a reduction of five loaves on the sack. Owing to the absence of gluten, this meal cannot be used to make ordinary bread, but it is often baked into cakes of various sorts. The *johnny* (corruption of 'journey') *cakes* of North America are unleavened, and are made of a rather coarse maizemeal.

¹ Thompson, Report to Food (War) Committee of the Royal Society, 1917.

Similar cakes constitute the *tortilla* of South America. The following is the composition of johnny cakes :¹

Water	..	..	..	..	..	38.0	per cent.
Protein	..	..	..	..	..	8.5	"
Fat	..	..	..	..	..	2.7	"
Carbohydrates	..	..	..	..	..	47.3	"
Mineral matter	..	..	..	..	..	3.5	"

On comparing this with the analysis of good white bread, given on p. 202, it will be seen that the comparison is all in favour of maize.

Sometimes the maize meal is leavened with yeast and subsequently baked in iron vessels. In this form it is known as *pone*, while in Ireland baking-powder is used, or the maize meal is mixed with flour and then converted into loaves. One-third of its weight of good flour is sufficient to enable fine maize meal to form good loaves. The colour of the bread is always rather dark, however, even if the proportion of wheat flour used be increased to one-half.

Various special preparations of maize deserve mention. *Hominy*, *cerealine* and *samp* are preparations of broken or split maize of various degrees of fineness. The composition of the first two is as follows :

					<i>Hominy.</i> ²	<i>Cerealine.</i> ³
Water	..	..	..	..	11.9	per cent.
Protein	..	..	..	..	8.2	"
Fat	..	..	..	..	0.6	"
Carbohydrates	..	..	..	..	78.9	"
Mineral matter	..	..	..	..	0.4	"

Both preparations are of high nutritive value and admirably adapted for making puddings, etc.

Cornflour, *maizena* and *oswego* are prepared from maize by washing away the protein and fat by means of dilute alkaline solutions, so that little but starch is left. Church states that cornflour contains only 18 grains of protein in every pound, and a sample of Brown and Polson's cornflour which the writer examined showed a mere trace of nitrogen. The following is an analysis of *maizena* :⁴

Water	..	..	..	..	..	14.3	per cent.
Protein	..	..	..	..	..	0.5	"
Carbohydrates	..	..	..	..	..	84.9	"
Mineral matter	..	..	..	..	..	0.3	"

These preparations must therefore be regarded simply as agreeable forms of starch, well adapted for food, provided they are taken along with some protein and fat carrier, such as eggs or milk, but by no means to be recommended on economic grounds.

¹ Analysis by Atwater and Wood.

² Analysis by the author.

³ Analysis by Atwater and Wood.

⁴ Given by Klemperer in Leyden's 'Handbuch der Ernährungstherapie,' p. 298.

A special small variety of maize is called in America *pop-corn*. When roasted it swells up and ultimately bursts. In this form it is known as 'popped pop-corn,' and is the basis of various sweets. Its composition is as follows:¹

					<i>Pop-corn</i> (<i>Raw</i>).	<i>Pop-corn</i> (<i>Popped</i>).
Water	..	..	..	..	10.8 per cent.	4.3 per cent.
Protein	..	..	..	..	11.2 "	10.7 "
Fat	..	..	..	..	5.2 "	5.0 "
Carbohydrates	..	..	..	..	71.4 "	78.7 "
Mineral matter	..	..	..	..	1.4 "	1.3 "

It is thus a valuable food.

*Corn Flakes*² consist of cooked maize which has been treated with malt-honey, dried, rolled and baked. It is a nutritious and digestible breakfast food.

Sugar-corn is a special variety of maize, containing much sugar. It is cooked while still green, and forms a sweet and succulent vegetable much esteemed in America.

Maize is not only a highly nutritive cereal from the chemist's point of view, but has the further advantage of being very well digested in the human body. Experiments show that its carbohydrates are almost completely absorbed, whilst the proteins are only slightly less thoroughly utilized than those of wheat.³

Maize must undoubtedly be regarded as a food of **great nutritive value**. 'With a diet of Indian corn bread and pork,' says an American writer,⁴ 'the workmen of this country are capable of enduring the greatest fatigue and performing the greatest amount of physical labour.'

It is also an **economical food**. It has been calculated⁵ that when maize and wheat are both selling at the same price per bushel one gets the same amount of digestible matter for a given sum in both. In wheat, however, one gets $2\frac{1}{2}$ pounds more protein, and in maize $2\frac{1}{2}$ pounds more carbohydrate. The fuel value in each case is almost precisely the same.

In view of these facts and of the approaching scarcity of wheat, one cannot help a feeling of regret that maize is not more widely adopted as a food amongst the working classes of this country. 'The cry of Europe,' says C. J. Murphy,⁶ 'is "cheap bread"; it is a bitter,

¹ Analysis by Atwater and Wood.

² Battle Creek Sanitarium Company, Ltd.

³ Rubner, *Zeit. f. Biolog.*, 1879, xv. 115. See also experiments by Malfatti, quoted by König, and footnote, p. 213. For a report on American experiments see *Farmers' Bulletin*, No. 298 (United States Department of Agriculture), 1907.

⁴ United States Department of Agriculture, Division of Chemistry, *Bulletin* 50, p. 11.

⁵ *Ibid.*, p. 14.

⁶ 'Report to United States Department of Agriculture on the Use of Maize in Europe,' p. 6.

agonizing cry, and we may best respond to it by instructing the toiling masses of the Old World in the excellence and cheapness of maize, and the proper methods of preparing it.'

BARLEY.

Barley is chiefly characterized by its richness in mineral matter. It contains more fat than wheat, but is comparatively poor in protein. The amount of starch in it varies in different samples from 39 to 57 per cent. (O'Sullivan). The whole grain when ground constitutes barleymeal. Scotch barley is the grain stripped of its husk and roughly ground. It is chiefly used as human food, however, in the form of either 'pearl' or 'patent' barley. The former consists of the whole grain polished after removal of the husk; the latter is simply pearl barley ground into flour. The composition of these preparations is shown in the Table (p. 189), and the following is an analysis of Robinson's Patent Barley by Leeds:

Moisture	..	..	..	..	..	10.10	per cent.
Protein..	..	..	..	..	..	5.13	„
Fat ..	..	..	..	..	..	0.97	„
Carbohydrates	..	..	..	..	..	81.87	„
Mineral matter	..	..	..	..	..	1.93	„

Barley contains but little gluten, in consequence of which its dough is too 'heavy' to make good bread. When mixed with half its weight of good wheat flour, however, barleymeal can be converted into good enough loaves.

Writing on the nutritive value of barley in 1872, Letheby said: 'Barleymeal is the chief food of a large number of people in the North of Europe and in the South of England, where the labourer is partly paid his wages in meal or grain. It is also used in Wales and Scotland, especially in winter-time, when wheaten bread is dear, and to some extent in Ireland. It is employed by about 90 per cent. of the out-door labouring population of England. At the time of Charles I. (1626), according to M'Culloch, it was the usual food of the ordinary sort of people, and as late as the middle of the last century hardly any wheat was used in the Northern counties of England. In Cumberland the principal families used only a small quantity of wheaten bread about Christmas-time. The crust of the everlasting goose-pie, which adorned the table of every county family, was invariably made of barleymeal.'

Since this was written barley has been steadily more and more displaced by wheat as an ordinary article of diet, and no doubt with considerable nutritive advantage.

As an article of diet in the sick-room, barley finds its chief use as the main ingredient of **barley-water**, a preparation which contains, however, but very little nutriment, as the following analysis by Wynter Blyth shows:¹

Water	..	..	..	..	..	99.27 per cent.
Fat	..	..	..	..	..	0.02 ..
Protein	..	..	..	..	..	0.03 ..
Starch	..	..	..	..	..	0.39 ..
Sugar	..	..	..	..	..	0.05 ..
Mineral matter	..	..	..	..	..	0.03 ..

It is chiefly of value on account of its demulcent properties.

RYE.

Next to wheat, **rye** is the great bread-making grain of the world. It contains less gluten than wheat, and the kind of gluten seems to be also chemically different, and as a result of this the bread derived from rye is apt to be rather moist and dense. An extreme example is the black bread, or pumpernickel, of North Germany.

The composition of the different flours derived from rye varies very considerably with the fineness of milling; but fine rye flour is much poorer in protein than flour of a similar grade produced from wheat.²

Fine rye bread is therefore poorer in building material than wheaten bread, but it is somewhat superior in this respect to bread made from maize.

The **digestibility** of fine rye bread is about equal to that of good wheaten bread; but the coarser varieties, especially pumpernickel, are very wasteful foods, 32 per cent. of the protein even in moderately fine rye bread being lost, as compared with 20 per cent. in white bread. In the case of pumpernickel the loss rises to 42 per cent.

RICE.

Rice is the poorest of all cereals in protein, fat and mineral matter. On the other hand, it has fully 76 per cent. of starch. The starch has the further advantage of being present in small and easily-digested grains. When boiled, rice swells up and absorbs nearly five times its weight of water, while some of its mineral constituents

¹ A series of analyses by Corlette (*Australasian Med. Gazette*, 1905, xxiv. 1) of barley-water prepared from two heaped teaspoonfuls of pearl barley to a pint of water showed that the average amount of starch in the product amounted to 2.03 per cent.

² *Vide* Falke, *Archiv f. Hygiene*, 1897, xxviii. 49, and Romberg, *ibid.*, 1897, xxviii. 244

are lost by solution. It is preferable, therefore, to cook it by steaming. Boiled rice has the following composition :¹

Water	52.7 per cent.
Protein	5.0 "
Fat	0.1 "
Carbohydrates	41.9 "
Mineral matter	0.3 "

Rice is only moderately easy of digestion in the stomach, $2\frac{1}{2}$ ounces cooked by boiling (*i.e.*, about two-thirds of a full soup-plateful) requiring three and a half hours for its disposal. This is probably to be attributed to the fact that it is not the function of the stomach to digest carbohydrates.

On the other hand, rice is absorbed with very great completeness in the intestine ; indeed, its solid constituents enter the blood almost as completely as those of meat. This is to be attributed to the comparative absence of cellulose. Practically none of the starch is lost, but the waste of protein amounts to 19 per cent.² It follows from this that rice is one of the foods which leave the smallest residue in the intestine, and this gives it a considerable value in some cases of disease.

The nutritive value of rice is much impaired by its poverty in protein and fat. Hence it is not adapted to be an exclusive diet, but should be eaten along with other substances rich in these two elements, such as eggs, cheese, or milk.³ Even as regards carbohydrate it would require about 1 pound 3 ounces of rice to furnish the daily need of an active man. This would entail the consumption of about 5 pounds of *cooked* rice daily.⁴

MILLET AND BUCKWHEAT.

These cereals^o are not used as human food in this country, although they are by no means of low nutritive value, but stand midway in that respect between wheat on the one hand and rice on the other. Millet is freely consumed in Africa, being the staple diet of the negroes of the Upper Nile, and in some Southern European countries, while in China it is used to make bread. The

¹ Analysis by Atwater and Woods.

² See Kumagawa, *Virchow's Archiv*, 1889, cxvi. 370.

³ It is interesting to note that in countries in which rice is largely used as a daily food this is actually done, as in the Italian *Risotto*, the Turkish *Pilaff*, and the Spanish '*Pollo con Riz*.'

⁴ It is worth observing, too, that in Eastern countries in which rice takes the place of bread it is eaten in a much drier, and therefore more concentrated, form than it is in Europe, and with the addition of various sauces and condiments to give it flavour and promote its digestion.

⁵ Buckwheat is not strictly a cereal, but belongs to the Polygonaceæ. It is considered here for convenience.

dhooora (sorgho-grass), or Indian millet, is of very similar composition. The following is an analysis of it given by Professor Church :

Water	..	..	..	..	..	12.2 per cent.
Protein	..	..	..	..	..	8.2 "
Fat	..	..	..	..	..	4.2 "
Carbohydrates	..	..	..	..	..	70.6 "
Cellulose	..	..	..	..	..	3.1 "
Mineral matter	..	..	..	..	..	1.7 "

Buckwheat is about equal in nutritive value to millet, but contains much more cellulose (10 per cent.). It is usually eaten in the form of a porridge. In this country it is hardly ever used as human food, but it is freely consumed in Brittany and Holland, and in some parts of the United States.

The published analyses of buckwheat are somewhat discordant. Church¹ gives the following as the composition of the grain when deprived of its husk :

Water	..	..	..	..	..	13.4 per cent.
Protein	..	..	..	..	..	15.2 "
Starch	..	..	..	..	..	63.6 "
Fat	..	..	..	..	..	3.4 "
Cellulose	..	..	..	..	..	2.1 "
Mineral matter	..	..	..	..	..	2.3 "

Another analysis² of buckwheat-flour was as follows :

Water	..	..	..	..	..	14.2 per cent.
Protein	..	..	..	..	..	9.2 "
Carbohydrates	..	..	..	..	..	73.3 "
Fat	..	..	..	..	..	1.8 "
Cellulose	..	..	..	..	..	0.8 "
Mineral matter	..	..	..	..	..	1.2 "

¹ 'Food': London, 1898 (Chapman and Hall), p. 93.

² Leyden's 'Handbuch der Ernährungs Therapie,' 2nd edition, 1903, i. 99.

CHAPTER XIII

THE PULSES—ROOTS AND TUBERS

The Pulses.

IN this group are included peas, beans, and lentils, and their allies. The edible parts of these resemble the grain of cereals in that they are to be regarded as storehouses of nourishment for the young plant. The chief chemical characteristic of the group is the **richness** of its members in **nitrogen**, in virtue of which fact they have been described as 'the poor man's beef.' All but from 3 to 5 per cent. of the total nitrogen, moreover, is in the form of protein (Church). Why the young pulse should require so much more nitrogen than the young cereal, it would be difficult to say, but perhaps it is on account of its greater rapidity of growth. It may be remembered that there is a special provision for the adequate supply of nitrogen to plants of this group in the form of little nodules on their roots, which nodules consist of masses of bacteria, possessed of the remarkable power of fixing the free nitrogen of the atmosphere and passing it on for the use of the plant.

The chief protein found in the pulses is called **legumin**,¹ also spoken of sometimes as vegetable casein, owing to its close resemblance to the principal protein of milk. So much is this the case, that a kind of cheese may actually be prepared from beans. Legumin is able to unite with salts of lime, and the resulting compound is not soluble in water. It is for this reason that peas and other pulses do not readily soften if the water in which they are soaked contains much lime, *i.e.*, is hard. The addition of a little bicarbonate of soda to the water throws down the lime. Hence the importance of adding soda to hard water in which pulses are to be soaked.² Magnesia, which resembles lime in so many other respects, has no effect upon legumin.³

The proteins of some of the pulses seem to be especially rich in sulphur, and this, by giving rise to sulphuretted hydrogen gas, helps to explain their tendency to produce flatulence. Beans are richer in

¹ A nucleo-albumin (*Maly's Jahres-Bericht Thier-Chemie*, 1897, xxvii. 21).

² Richter has shown (*Archiv f. Hygiene*, 1903, xlv. 264) that peas are not so well digested and absorbed when boiled in hard water as they are when cooked in soft.

³ See Strümpell, *Deut. Archiv f. Klin. Med.*, 1876, xvii. 108.

sulphur than peas, while lentils contain least of all. The ash of the pulses is poorer in phosphorus than that of the cereals, but richer in potash and lime. The pulses, indeed, contain more of the latter ingredient than any other form of vegetable food.

The pulses are well supplied with carbohydrates, but are poor in fat. For this reason they go well with fatty foods (*e.g.*, bacon and beans, pork and pease pudding), and are improved by being served with sauces containing butter, or cooked with oil. They also contain a bitter principle which renders them unpalatable to many persons. It should be added that they contain considerable quantities of purin-bodies, in consequence of which the excretion of uric acid is greater after their use. For this reason they are sometimes forbidden to the gouty. Dried peas and beans require prolonged soaking in order to soften their skins. Even haricots, in which the skin is comparatively thin, require about eight hours to soften. The water in which they are soaked should be soft or boiled. The reason for this was given above. The soaking is inevitably accompanied by some loss of protein and mineral matter, and also of carbohydrates; but it has the advantage of removing most of the bitter principle in the seeds. The amount of water taken up is very great. The proportion of water in dried haricot beans, for example, rises as the result of soaking and boiling from 14 per cent. up to 73 per cent., and in the case of peas the increase is from 9·7 up to 86·9 per cent.¹ This increase in water means, of course, a corresponding increase in the weight and bulk of the food, and must always be taken into account when comparing the relative nutritive values of the pulses and meat.

The pulses are **not readily digested** by the stomach. As Galen said: 'They are harder to digest than other foods and give bad dreams.' This is no doubt partly owing to their bulkiness when cooked. Thus, $5\frac{1}{3}$ ounces (150 grammes) of lentils in the form of a mash, or about a soup-plateful, remained in the stomach for four hours, and 200 grammes of peas in a similar form for four hours and a quarter. An equal weight of French beans (*haricots verts*) remained rather longer even than that.

If properly prepared, the pulses are absorbed in the intestine very thoroughly. Thus the protein of pea or lentil flour is all taken up except about 8 or 9 per cent.² when 200 grammes (7 ounces) are given daily. Even when the amount given was as much as 600 grammes ($21\frac{1}{2}$ ounces) the loss was only as follows:³

¹ Analyses by Katherine J. Williams, *Journ. of Chem. Soc.*, 1892, lxi. 226.

² Strümpell, *Deut. Archiv f. Klin. Med.*, 1876, xvii. 108.

³ Rubner, *Zeit. f. Biolog.*, 1880, xvi. 119.

Dry substance	..	..	..	..	9.1 per cent.
Protein	..	..	..	..	17.5 "
Carbohydrate	..	..	..	..	3.6 "
Mineral matter	..	..	..	..	32.5 "

This shows that the protein of the pulses, if given in a state of fine division, is capable of very good absorption—almost as good, indeed, as that of gluten when given in the form of macaroni, in which the loss is 11.2 per cent., and considerably better than gluten when taken in the form of white bread (loss about 20 per cent.). On the other hand, the loss is very much greater if the food is not given in a state of fine division. It was found, for example, that if the lentils were simply boiled soft and taken along with broth, the loss of protein rose to 40 per cent.¹ It will be noted that there was a small loss of carbohydrate even on pea flour. The amount of it, however, is less than in the case of potatoes or carrots, but in white bread, it will be remembered, there is no loss of carbohydrate at all.

Some extensive investigations on the absorption of different forms of legumes have been made in recent years in America.² They showed an average absorption of 80 per cent. of the protein and 97 per cent. of the carbohydrates. These results are very favourable when it is remembered that the legumes constituted the major part of the diet in the subjects studied.

The nutritive value of the pulses is undoubtedly high. Especially is this the case if they be regarded as sources of protein. It would require about 600 grammes ($1\frac{1}{2}$ pounds) of pea flour to supply the amount of protein required daily by an active man. Suppose this were to be given in the form of pea soup. A good thick soup would contain 25 grammes—a heaped tablespoonful—in each plate. The protein value of this would be equal to an ounce of meat. Twenty-four platefuls of such a soup, then, would require to be taken in the day. By making the soup with milk instead of water—an excellent plan—the amount of protein in it would be trebled, and eight platefuls would suffice.

The 600 grammes of pea flour would hardly, however, contain as much carbohydrate as is required, and would be very deficient in fat. These deficiencies would require to be made good by the addition of some other articles to the diet, or by increasing the amount of pea flour consumed. As a matter of fact, it has been found that when the quantity of peas eaten amounts to 960 grammes ($34\frac{1}{2}$ ounces) in the twenty-four hours, all the demands of nutrition are

¹ Strümpell, *Deut. Archiv f. Klin. Med.*, 1876, xvii. 108.

² Studies on the Digestibility and Nutritive Value of Legumes (United States Department of Agriculture, Office of Experiment Stations, Bulletin 187, 1907).

satisfied;¹ but it is very doubtful whether anyone could go on consuming this quantity for any length of time. It comes then to this, that, while the pulses are most valuable sources of protein, they are not adapted to be the exclusive diet of health. As a cheap and efficient method of supplementing the deficiency of nitrogen in a purely vegetable diet, however, their use is strongly to be recommended, and it is a pity that they are not more largely taken advantage of by those to whom economy is of importance, for unquestionably the pulses are amongst the cheapest of foods, and a given sum will yield more protein, if invested in them, than in any other way (see Plate III.). It remains to add a few words about the individual members of the pulse group. Their chemical composition is shown in the following tables:

COMPOSITION OF PULSES. (*The Means of Many Analyses.*)

	Water.	Protein.	Carbo- hydrates.	Fat.	Cellu- lose.	Mineral Matter.
Green peas	78.1	4.0	16.0	0.5	0.5	0.9
Dried „	13.0	21.0	55.4	1.8	6.0	2.6
Prepared pea flour ..	10.21	27.98	56.93	1.97	0.42	2.49
Lentils	11.7	23.2	58.4	2.0	2.0	2.7
Horse beans (dry) ..	13.1	25.5	50.9	1.7	5.5	3.3
Broad or Windsor beans (dry)	8.4	26.4	58.6	2.0	1.0	3.6
French beans (haricots verts)	89.5	1.5	7.3	0.4	0.6	0.7
Haricots (haricots blancs)	11.7	23.0	55.8	2.3	4.0	3.2
Scarlet runners (stewed)	91.12	1.7	3.7	0.3	2.9	0.3
Soy beans	11.0	32.9	28.7	18.1	4.4	4.9
„ bean flour	9.3	39.5	28.2	13.7	4.0	5.3
Peanuts	8.3	24.0	17.0	44.3	4.5	1.9
Butter beans (ground unpeeled)	10.5	20.6	62.6	2.0	—	4.3

The following give some analyses of dried pulses by Balland.²

	BEANS (HARICOTS).		LENTILS.		PEAS.	
	Mini- mum.	Maxi- mum.	Mini- mum.	Maxi- mum.	Mini- mum.	Maxi- mum.
Water	10.00	20.40	11.70	13.50	10.60	14.20
Protein	13.81	25.16	20.32	24.24	18.88	23.48
Fat	0.98	2.46	0.58	1.45	1.22	1.40
Starch and sugar ..	52.91	60.98	56.07	62.45	56.21	61.10
Cellulose	2.46	4.62	2.96	3.56	2.90	5.52
Ash	2.38	4.20	1.99	2.66	2.26	3.50

The garden pea (*Pisum sativum*) is eaten either fresh (green peas) or dried. Green peas cooked in the usual way contain from 12 to

¹ Rubner, *loc. cit.*

² *Compt. Rend.*, 1897, cxxv. 119.

16 per cent. of carbohydrate, of which a considerable proportion is sugar. Of beans there are several edible varieties. The French or kidney bean (*Phaseolus vulgaris*) is eaten either in the young state along with the pod (haricots verts), or the seeds are consumed alone either fresh or after drying (haricots blancs). The amount of cellulose in the pod causes it to be digested and absorbed with difficulty, and on that account it is a wasteful form of food. Allied to the French bean is the scarlet runner (*Phaseolus multiflorus*), which when stewed constitutes 'Turkish beans.' The broad or Windsor bean (*Faba vulgaris*) is eaten either in the fresh or dry state. A coarser variety of the same plant is the horse or field bean. It is not usually consumed as human food.

Beans are on the whole richer in protein than peas, but contain also more sulphur, and are more apt to cause flatulence.

The Lentil (*Lens esculenta*) is even richer in protein than either the pea or the bean, and, as a rule, the smaller varieties of it are richer in that constituent than the larger. Egyptian lentils are amongst the best. Lentils contain little sulphur, and are more digestible and less apt to cause flatulence than either peas or beans. The ash of the Egyptian lentil is particularly rich in iron.

The patent preparation known as **Revalenta Arabica** consists mainly of lentil flour. The following is the result of an analysis which I recently made of it.

Moisture ..	9.1 per cent.	Carbohydrates ..	65.2 per cent.
Protein ..	22.0 "	Mineral matter ..	2.2 "
Fat ..	1.5 "		

It is really poorer in nitrogen than pure lentil flour. The latter costs 2½d. per pound; Revalenta, 3s. 6d. It certainly in no way merits the very high claims sometimes advanced for it. A soup-plateful of Revalenta made from three moderately-heaped table-spoonfuls (60 grammes) yields thirty-six Calories less than a similar quantity of good porridge, but is slightly richer in protein and mineral matter. In other words, it is rather more valuable as a tissue-builder than porridge, but is not so good as a source of heat or energy. It must be remembered, too, that it is considerably more expensive.

The **Soy¹ Bean** (*Glycine hispida*) is the richest of all the pulses in protein, and has also a large amount of fat, but very little starch.² For this reason it is of use as a bread substitute in diabetes, a flour

¹ Also called 'Soya' Bean.

² Holmes (*Journ. Amer. Med. Assoc.*, 1920, 74, 798), in experiments on the digestibility of steamed soy beans and peanuts, found that even in large quantities they were very well absorbed.

being prepared from it and made into loaves or biscuits. In China and Japan it is extensively eaten in the form of soy cheese, and as various sauces and pastes, all of which are rich in protein and so are fitted to supplement the deficiencies of rice. It is also grown in Southern Europe. A very interesting 'synthetic' milk ('Solac') has been prepared from the soy bean, which has a close resemblance in physical and chemical properties to cow's milk, and is able to replace the latter to a large extent for many purposes.

The **Peanut** (*Arachis hypogæa*), although botanically one of the pulses, really resembles more closely the true nuts. Like these, it is rich in proteins and fat, and may be used as a diabetic food. It enters into the composition of the patent food known as 'Nutrose,' and after expression of the oil it forms cakes for cattle.

Roots and Tubers.

We have already seen that the chief bulk of the grain of cereals is to be regarded as a storehouse of nutriment for the use of the young plant. The roots and tubers, the consideration of which will occupy our attention in this section, may be regarded in like manner as reserves of nourishment for the use of the adult plant itself. During the prosperous days of spring and early summer the plant lays by of its superfluity against the certain adversity of autumn. The reserve nutriment so laid up is almost entirely in the form of carbohydrates—chiefly starch. Protein and fat are scarcely represented at all. Hence it is obvious that in using the roots and tubers as foods we are tapping a supply of only one of our nutritive elements, and that fact must never be lost sight of in estimating the value of this class of vegetable foods.

It remains to be added that, of the small proportion of nitrogenous matter which these foods contain, only part, and that not infrequently a very small part, is present in the form of protein. On the other hand, they are by no means destitute of mineral ingredients, mainly salts of potash, and the presence of these confers upon the roots and tubers a greater value as articles of diet than they would otherwise be entitled to possess.

As far back as the year 1781, Letheby tells us, Sir Gilbert Blane, in his work on 'Diseases of the Fleet,' alluded to the beneficial action of the potato in scurvy; and the late Dr. Baly remarked, in his inquiries into the diseases of prisoners, that wherever potatoes were used scurvy was unknown.

Another general consideration which must be borne in mind is that the mere cooking of these foods robs them of a very large

proportion of their mineral ingredients and of some of the nitrogenous matter in which they are already so deficient. For this reason the water in which they are cooked should also be utilized as far as possible, or, which is preferable, they should be cooked by means of steam.

AVERAGE COMPOSITION OF EDIBLE PORTION OF ROOTS AND TUBERS.

			Water.	Protein.	Carbo- hydrate.	Fat.	Fibre.	Ash.	Extrac- tives.
Potatoes	..	..	78·3	2·2	18·0	0·1	0·4	1·0	1·4
Carrots	..	..	85·7	0·5 (Albuminoid N x 6·25)	10·1	0·3	1·5	0·9	1·0
.. (cooked)	..	..	93·4	0·53	3·39	0·17	1·8	0·14	
Turnips	..	..	90·3	0·9	5·0	0·15	1·8	0·8	1·1
.. (cooked)	..	..	97·25	0·32	0·65	0·06	1·2	0·32	
Radishes	..	..	90·8	1·4	4·6	0·1	—	0·7	
Beetroots	..	..	83·9	0·5	11·0 (10 per cent. of sugar)	0·1	3·0	0·9	1·0
.. (cooked)	..	..	94·8	0·44	2·83	0·06	1·3	0·3	
Parsnips	..	..	80·1	1·4	14·1	1·0	2·1	1·3	
.. (cooked)	..	..	97·28	0·22	1·46	0·29	0·72	0·12	
Artichokes	..	..	79·8	2·3	14·5	0·3	2·0	1·0	
.. (cooked)	..	..	91·6	1·8	4·6	0·08	0·9	0·61	
Onions..	..	..	89·1	1·6	6·3	0·3	2·0	0·6	
Sweet potatoes	..	..	72·9	1·6	22·5	0·5	1·8	0·7	
Yams	..	..	79·6	2·2	15·3	0·5	0·9	1·5	

As regards the digestibility of these foods as a class, it may be said that it depends largely on the amount of cellulose which each happens to contain, but it is true of all of them that they are **only indifferently absorbed**, and are prone, by reason of their bulk, to derange the stomach and bowels if eaten in large quantity.

We may now pass to a detailed examination of the chief members of the group, beginning with the potato.

POTATOES.

The potato was introduced into this country more than 300 years ago,¹ and since that time it has steadily increased in popular favour, until it may now be regarded as one of the most important staple articles of diet.

¹ A full account of the history of the discovery of the potato will be found in Weyl's 'Handbuch der Hygiene,' iii. 257.

If one cuts a raw potato across with a sharp knife and looks at the cut surface, three distinct layers can easily be made out (Fig. 18). These are (1) the

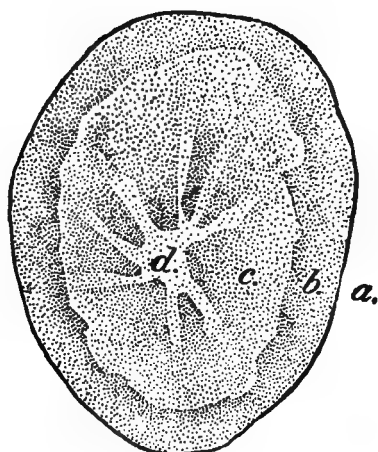


FIG. 18.—CROSS SECTION OF A POTATO.
a, Skin; b, Fibro-vascular layer; c, Outer zone of flesh; d, Central core.

(Fig. 18). These are (1) the thin outer skin. (2) A broader layer inside the skin called the 'fibro-vascular layer.' It contains a small amount of pigment, and turns green when exposed to the light, giving the potato an unpleasant taste. (3) The flesh of the potato, which makes up the rest of its bulk. On more careful inspection this is seen to be divided into a central core and an outer zone which surrounds it.

These different layers form the following proportions of the whole potato:

1. Outer rind .. = $2\frac{1}{2}$ per cent.
2. Fibro-vascular layer .. = $8\frac{1}{2}$..
3. Flesh = 89 ..

The importance of recognising them is due to the fact that they differ considerably in chemical composition, as is shown in the following table:¹

COMPOSITION OF A POTATO.

	Water.	NITROGEN.		Fat.	Carbo- hydrate.	Mineral Matter.
		As Protein.	Total.			
Outer rind	80.1	0.25	0.43	0.8	14.6	1.8
Fibro-vascular layer ..	83.2	0.24	0.36	0.1	13.3	1.1
Flesh	81.1	0.18	0.32	0.1	16.0	0.8
Whole potato	81.3	0.19	0.32	0.1	15.7	0.9

The fibro-vascular layer is seen to be considerably richer in mineral matter and protein than the flesh, and in peeling it off with the rind we lose these valuable ingredients.

If the flesh of the potato is squeezed it can be separated into a solid part and a juice. The former consists mainly of starch; it has only 15 per cent. of the nitrogenous matter. The juice consists of

¹ See Bull. 43, United States Department of Agriculture, Office of Experiment Stations, Washington, 1897.

water holding in solution nitrogenous matter and salts. It contains fully 85 per cent. of the total amount of nitrogenous matter contained in the potato.

It must be clearly realized that by no means all of this nitrogenous matter is present in the form of protein. Of the total amount of nitrogen in a potato, only 49 per cent. is contained in proteins, the remainder being in the form of ammonia compounds (amides, *e.g.*, asparagin) and salts. The failure to recognise this fact has led people to assume that the whole of the nitrogen of the potato represents protein, and so greatly to overrate the value of potatoes as tissue-building food.

The richer the potato is in protein—in other words, the juicier it is—the more ‘waxy’ is it when cooked, for the coagulated protein holds together. For this reason young potatoes, which contain more juice than those which are older and more starchy, have a more solid and waxy consistence when cooked than the latter.

The richness of the potato in starch is its most striking chemical characteristic, and causes it to be one of the chief commercial sources of that substance. Dextrin and ‘British arrowroot’ and many other things are prepared from it. The starch grain of the potato is of specially large size, and seems to be more easily attacked by ferments than most forms of starch, probably because it does not contain much ‘starch cellulose.’ Owing to their readiness to undergo fermentation potatoes should be avoided in some diseased conditions, such as dilatation of the stomach.

The most important mineral ingredients of potatoes are salts of potash, and potatoes are one of the chief sources from which we obtain our supply of these salts. Part of the potash is united with citric acid. Potatoes, like all tubers, may have their composition, and consequently their nutritive value, profoundly modified by the mode in which they are cooked. The chief danger is that their nitrogenous constituents and mineral salts may be dissolved out. The amount of starch and water which they contain is scarcely ever affected.¹ These facts are brought out in the following analyses:²

¹ See analyses of cooked potatoes by Katherine Williams, *Journ. of Chem. Soc.*, 1892, lxi. 226.

² United States Department of Agriculture, Office of Experiment Stations, Bull. 43, p. 30.

THE LOSS OF MATERIAL DURING THE PROCESS OF COOKING POTATOES.

	Dry Matter.	NITROGEN.			Carbo-hydrates.	Ash.
		Protein.	Non-Protein.	Total.		
<i>Skins removed before Boiling.</i>						
Water cold at beginning of test	Per cent. 3·7	Per cent. 4·3	Per cent. 12·9	Per cent. 8·3	Per cent. 2·5	Per cent. 17·0
Water hot at beginning of test	4·0	3·3	17·9	10·0	2·8	17·4
Average	3·9	3·8	15·4	9·2	2·7	17·2
<i>Boiled with Skins on.</i>						
Water cold at beginning of test	0·3	0·6	0·6	0·6	0·2	1·9
Water hot at beginning of test	0·3	0·4	1·7	1·0	0·1	1·2
Average	0·3	0·5	1·1	0·8	0·2	1·6

The kind of water in which they are soaked does not make any difference. It has been calculated that if a bushel of potatoes were peeled and soaked before being boiled the loss of nutrients would be nearly equivalent to the amount contained in 1 pound of beefsteak. It follows from this that potatoes should either be steamed or cooked in their 'jackets.'

The accompanying diagram shows the percentage composition of a potato, and the loss of nutrients which it sustains when cooked by the usual method.

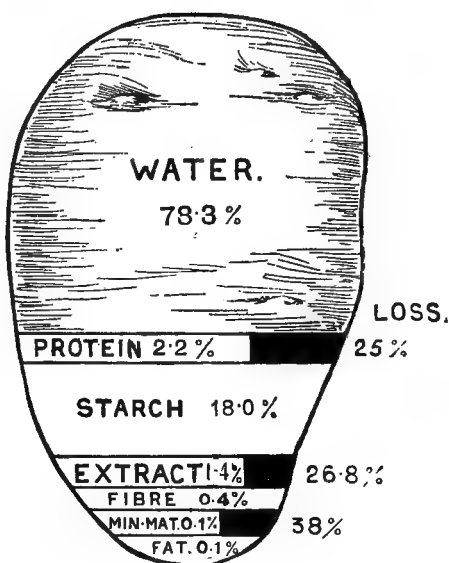


FIG. 19. — PERCENTAGE COMPOSITION OF A POTATO AND LOSS OF EACH CONSTITUENT ON BOILING.

The composition of raw and cooked potatoes from the average of many American analyses is as follows :¹

Kind of Food.	Refuse.	Water.	Protein.	Fat.	Carbohydrates.		Ash.	Fuel Value per Pound.
					Sugar, Starch, etc.	Crude Fibre.		
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Calories.
Potato, as purchased ..	20.0	62.6	1.8	0.1	13.8	0.9	0.8	310
Potato, edible portion ..	—	78.3	2.2	0.1	18.0	0.4	1.0	375
Potato, boiled ..	—	75.5	2.5	0.1	20.3	0.6	1.0	440
Potato, mashed and seasoned ..	—	75.1	2.6	3.0	17.8		1.5	505
Potatoes fried in fat, 'Potato chips' ..	—	2.2	6.8	39.8	46.7		4.5	2,675
Potato, evaporated ..	—	7.1	8.5	0.4	80.9		3.1	1,680
White bread ..	—	35.3	9.2	1.3	52.6	0.5	1.1	1,215

The digestibility of potatoes in the mouth and stomach depends largely on the form in which they are eaten. They are less digestible when eaten as lumps than in a purée; and 'mealy' potatoes are more digestible than 'waxy.'

Two medium-sized potatoes (weighing together $5\frac{1}{2}$ ounces) when boiled and eaten in the usual way remain for about two to two and a half hours in the stomach—that is, a shorter time than a similar weight of bread.

In the intestine potatoes are, on the whole, very well absorbed. This is owing to the fact that they contain much starch and little cellulose. Even when the quantity consumed daily amounts to $3\frac{1}{2}$ pounds, $92\frac{1}{2}$ per cent. of the starch and 70 per cent. of the total nitrogen enters the blood.

Potatoes are, however, by no means suited to constitute the sole, or even the staple, diet of man. They are much too bulky, and contain too little protein in proportion to their starch. Thus, it would require about 22 pounds of potatoes to yield even 118 grammes of protein daily, while this quantity would contain more than four times as much carbohydrate as one really needs. As a matter of fact, however, Rubner has found that $6\frac{1}{2}$ pounds of potatoes are enough to furnish 3,000 Calories of energy and to prevent any loss of bodily protein. This is probably to be explained by the relatively enormous quantity of carbohydrates (*i.e.*, protein-sparers) which such a diet contains.²

An experiment mentioned by Pereira³ illustrates this fact very well. In the year 1840 some experiments with a potato diet were

¹ United States Department of Agriculture, Farmers' Bulletin 295, 1907.

² There is some evidence that the nitrogenous constituents of potatoes are nearly twice as valuable for the repair of tissues as those of bread.

³ 'Food and Diet,' p. 372.

made in a prison at Glasgow. Ten of the prisoners, consisting of young men and boys, were put on a diet of 6 pounds of potatoes daily. At the end of the experiment (the duration of which is not stated) the majority of the subjects had gained considerably in weight, and all expressed themselves as quite satisfied with the potatoes, and regretted the change back to ordinary fare. It must be added, however, that these prisoners were only engaged in light work, and the state of their nitrogen balance was not investigated.

Even granting that 6 pounds of potatoes per day is sufficient to supply fully all the needs of the body, it must be evident that this quantity is still unduly **bulky**, weighing as it does about twice as much as an ordinary mixed diet. The result of its continued use would be an undue burdening of the stomach and bowels, culminating in dilatation, if not disease, of these organs. The so-called 'potato belly' of the Irish peasant is an example of such a result.

It must also be borne in mind, in estimating the nutritive value of potatoes, that much of their nitrogen is in the form of substances which do not belong to the protein group. Of these substances **asparagin**¹ is one of the chief. It contains 21.2 per cent. of nitrogen. Now, the direct nutritive value of asparagin is nil, but there is reason to believe that it plays a useful part in the intestine by limiting putrefaction, and so sparing proteins from destruction. It may also promote the absorption of proteins and carbohydrates into the blood. In the case of herbivorous animals these functions may be useful, but in carnivora and mixed feeders, which eat plenty of protein, they are superfluous.²

As regards **economic value**, potatoes must be regarded as a cheap, but by no means the cheapest, kind of food. Thus, when potatoes are selling at 1d. and bread at 1½d per pound the former are two or three times dearer than the latter.³ From the point of view of national economy, however, potatoes are undoubtedly a cheap food. Thus, Boussingault found that a given piece of land produces :

			<i>Wheat.</i>	<i>Rye.</i>	<i>Peas.</i>	<i>Potatoes.</i>
Protein	..	..	510	440	560	950
Starch	..	..	1,590	1,196	780	6,840
Ash	..	..	90	62	60	323

Allied to the potato, though not now eaten in this country, are the sweet potato and the yam.

¹ Asparagin = amido-succinamic acid.

² See Kellner, *Maly's Jahres-Bericht Thier-Chemie*, 1897, xxvii. 721, and Gabriel, *Zeit. f. Biolog.*, 1892, xxix. 115; also König, 'Nahrungsmittel Chemie,' Bd. 1, p. 119, and F. Voit, 'Ergebnisse der Physiologie,' I., Abth. 1, 1902.

³ Smith, 'Foods,' p. 200.

The **Sweet Potato** (batatas) is cultivated in hot countries, and is largely eaten in the United States. It used to be eaten in England before the present potato was introduced, and it is to it that Shakespeare refers when he makes Falstaff say, 'Let the sky rain potatoes!'

The **Yam** is the tuber of a tropical climbing plant and is much larger than the potato, but resembles it in taste.

The composition of the sweet potato and yam is represented in the table on p. 237. They are fully equal to the ordinary potato in nutritive value.

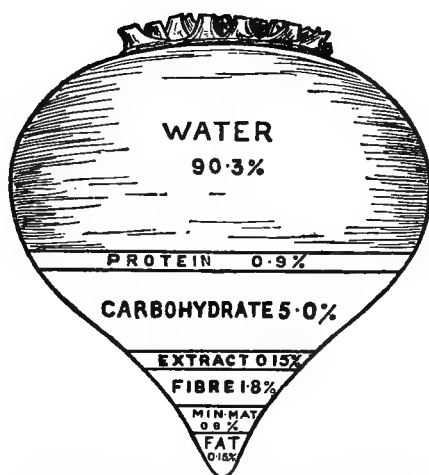


FIG. 20.—PERCENTAGE COMPOSITION OF A TURNIP.

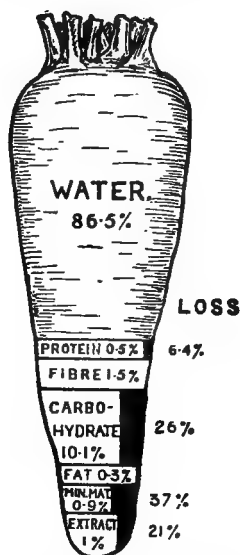


FIG. 21.—PERCENTAGE COMPOSITION OF A CARROT, AND LOSS OF EACH NUTRITIVE CONSTITUENT BY BOILING

THE TURNIP.

The chemical composition of a **turnip** is graphically represented in Fig. 20. It is difficult to realize that an apparently solid object like a turnip really contains more water than a fluid like milk; yet such is the fact. A turnip contains almost no protein, most of its nitrogen being in a non-protein form. Carbohydrates are more abundantly represented than any other nutritive ingredient, but even they only amount to 5 per cent. Curiously enough, none of this is in the form of starch, that substance being left out in the turnip's composition.

'Pectose' bodies make up the bulk of the carbohydrate present. The nutritive value of these has already been discussed (p. 163). Seeing that starch and sugar are absent, there seems to be no reason why turnips should be forbidden to diabetics.

A consideration of the above facts shows that the turnip can never be regarded as an important form of food, a conclusion which is accentuated by the fact that the white turnip eaten at the table, though finer in flavour, is of even less nutritive value than the coarser 'swede.'

Carrots are decidedly more nutritious than turnips, mainly owing to their richness in sugar, of which they contain nearly 10 per cent. either as cane or fruit sugar. The amount of protein which they possess is a negligible quantity, but their mineral salts are of some value. The composition of a carrot, and the loss of nutrients which it sustains on boiling, are represented in Fig. 21.

It has been found¹ that the following is the loss of nutrients from the intestine on a diet of carrots and fat :

Total solids lost	..	..	..	= 20·7 per cent.
„ nitrogen lost	..	..	..	= 39·0 „
„ carbohydrates lost	..	..	..	= 18·2 „
„ mineral constituents	..	..	..	= 33·8 „

Carrots cannot, therefore, be regarded as at all a digestible form of food. Nor are they easily disposed of by the stomach, for 5½ ounces remain there for three hours and twenty minutes.

Compared with the turnip and carrot, a raw Beetroot is a comparatively valuable source of food. Here, again, this is owing to the fact that it contains a large amount of cane-sugar. The ordinary garden beet contains nearly as much sugar as the 'sugar beet,' and by special cultivation the latter can be made to contain 15 per cent. of cane-sugar. In the process of cooking, however, much sugar is lost, so that ordinary beetroot as it comes to the table does not contain more than 3 per cent.

Like the carrot and turnip, the beetroot is of almost no value as a source of protein. It contains altogether less than 2 per cent. of nitrogenous matter, and even of this only a fraction is in a protein form. The exact proportions are :

35 per cent. of total nitrogen	..	= protein.
39 „ „ „	..	= amides.
36 „ „ „	..	= ammonia salts and nitrates.

The beetroot is also richer in cellulose than most tubers. The addition of vinegar to slices of beetroot helps to soften the latter,

¹ Rubner, *Zeit. f. Biolog.*, 1879, xv. 115.

while it does not interfere with the digestion of the other carbohydrates, seeing that these are already in the form of sugar.

Parsnips belong to the same order as the carrot. In the raw state they are fairly rich in starch and sugar, but lose much of the latter in the process of cooking.

Jerusalem artichokes resemble turnips in containing no starch, but are fairly rich in carbohydrates belonging to the gummy series, which make them very mucilaginous when boiled. They also contain a little sugar and about 2 per cent. of the peculiar carbohydrate **inulin**, the nutritive value of which is unknown. It is certainly better borne by diabetics than other forms of carbohydrate, and may be allowed in mild cases (Von Noorden). About half of the nitrogen artichokes contain is in a non-protein form.

Onions are chiefly valued for their pungent oil, which makes them useful flavouring agents. They are thus to be regarded as condiments rather than foods. The large Spanish onion, however, is richer in nutrients, and may rank as a food. Onions are valuable in cases of constipation, probably owing to their richness in cellulose.

TAPIOCA, SAGO AND ARROWROOT.

These are to be regarded simply as special forms of starch.

Tapioca is derived from the roots of South American cassava plants belonging to the Spurge order (Euphorbiaceæ). Curiously enough, one of these—the bitter cassava (*Manihot utilissima*)—contains, mixed up with the starch, a milky juice in which is present a good deal of that dangerous poison prussic acid. In preparing tapioca the juice is washed away from the grated root and the starch allowed to settle. It is then collected and dried on hot metal plates. The process of drying has the effect of rupturing most of the starch grains. Tapioca as found in the market contains about 11½ per cent. of water and 87½ per cent. of starch, along with traces of protein and mineral matter, and has a fuel value of 1,650 Calories per pound. Pure starch contains only 2 per cent. of water, and a pound of it furnishes 1,825 Calories, so that weight for weight pure starch is considerably more nourishing than tapioca.

Tapioca remains a considerable time in the stomach. Forty grammes of it in the form of a thick gruel (about a soup-plateful) had not entirely left the stomach until after the lapse of two hours and forty minutes (Penzoldt). Its use should, therefore, be avoided in cases in which it is desirable to lighten the labours of the stomach.

Experiments upon the absorption of tapioca in the intestine have

not been performed, but consisting as it does of starch alone, one would expect it to be absorbed very completely.

Sago is derived from the pith of the sago palm. The trees are felled, split, and the starch washed out. It is then dried, and converted into pearl sago by granulating. One tree should yield about 500 pounds of sago. Commercial sago contains 86·7 per cent. of starch.

Arrowroot is obtained from the rhizome of a West Indian plant (*Maranta arundinacea*). The roots are mashed up, mixed with water, and the starch allowed to settle. When dried, it constitutes ordinary arrowroot. The superiority of **Bermuda arrowroot** to the other varieties is due to greater care in manufacture. The starch, having been washed away from the mashed roots and strained through muslin, is allowed to settle, and is subsequently dried in flat copper pans covered with gauze. When dry, it is packed by means of German-silver shovels into new barrels lined with paper stuck in with arrowroot paste. All these precautions are necessary to prevent the arrowroot from becoming contaminated, as it is so apt to be, by foreign flavours. For a similar reason it is exported on deck under covers, lest it may be affected by effluvia from the cargo in the hold.

Arrowroot contains $16\frac{1}{2}$ per cent. of water, and $82\frac{1}{2}$ per cent. of starch, along with only about 0·8 per cent. of protein and 0·2 per cent. of mineral matter.

The composition of these preparations when cooked by boiling and ready for eating is as follows:¹

			<i>Sago.</i>		<i>Arrowroot.</i>
Water	..	..	89·00	per cent.	93·41 per cent.
Protein	..	..	1·38	"	0·30 "
Fat	..	..	0·04	"	trace "
Starch	..	..	9·37	"	6·10 "
Cellulose	..	..	0·01	"	0·01 "
Mineral matter	..	..	0·08	"	0·02 "

Tous les Mois resembles arrowroot very closely. It is derived from the root of *Canna edulis*, a West Indian plant. It has an extraordinarily large starch grain—the largest known, indeed; but apparently it is poor in starch cellulose, for it is very easily digested, and makes excellent blancmange.

Salep is a starchy preparation derived from the roots of various species of orchis, and imported into England from Smyrna.

The **digestibility of arrowroot** and its allies in the stomach is probably much the same as in the case of tapioca, and their absorp-

¹ Analyses by Katherine J. Williams (*loc. cit.*, footnote p. 239).

tion in the intestine is exceedingly complete. This gives them a special value in the treatment of diarrhœa.

As regards the **nutritive value** of all these preparations, it must be remembered that they are simply agreeable forms of starch; in other words, they consist almost entirely of carbohydrate, and should therefore not be eaten alone, but along with substances rich in protein and fat. Eggs and milk are typical examples of such substances, and accordingly one finds that people have made puddings of tapioca, sago, or arrowroot along with milk and eggs before anything was known of the chemical constituents of the diet. **Tapioca pudding** has something like the following composition:

Water	..	..	..	..	..	61.8	per cent.
Protein	..	..	..	..	..	3.6	"
Fat	..	..	..	..	..	3.7	"
Carbohydrates	..	..	..	..	..	30.0	"
Mineral matters	..	..	..	..	..	0.9	"

and has a fuel value of about 780 Calories per pound (Atwater). It must be regarded as a highly nutritious food.

A cupful of **water-arrowroot** contains only about 30 grains of starch. It would furnish to the body about 9 Calories of fuel value, while even an invalid requires about 2,000 Calories daily.

When one considers the **economy** of these different preparations, one may say that tapioca and sago are worth the price paid for them, while the better qualities of arrowroot certainly are not. Starch at 4d. a pound is really rather dearer than tapioca at 3d. or sago at 2d., even although it contains 10 per cent. more nutriment. Apart altogether from that also, one cannot eat pure starch, whereas the **same** chemical substance in the form of tapioca or sago is quite agreeable. On the other hand, Bermuda arrowroot at 2s. 9d., or even 1s. 6d., the pound is a purely luxurious article. The cheaper kinds at 4d. to 5½d. are quite as nutritious, and there can be no physiological objection to the substitution for a genuine article of the so-called **Farina** or **English arrowroot**, prepared from the starch of maize or potatoes, at 3d. per pound. Even although it requires more of these to make a jelly than of the genuine arrowroot, yet this difference is far more than made up for by the difference in price.

CHAPTER XIV

VEGETABLES—FRUITS—NUTS—FUNGI—ALGÆ AND
LICHENS

Vegetables.

THE leaves of **green vegetables** are to be regarded as the lungs of the plant to which they belong. They are merely a sort of framework on which the green colouring matter,¹ by which the plant feeds and breathes, is spread out. In no sense are they, like the roots, storehouses of reserve nutriment. One would not, therefore, expect that such leaves would have high nutritive value, and chemical analysis entirely confirms the expectation. Speaking generally, it may be said that green vegetables contain a great deal of water, almost no nitrogenous matter² or fat, and only a small quantity of carbohydrates (2 to 8 per cent.). This small proportion of carbohydrates renders their use, especially as carriers of fat, admissible in diabetes. Their framework contains a good deal of cellulose. The amount of mineral matter which they contain is relatively large, and confers upon them much of what value they possess as foods. They are also of great value as a source of vitamins.

COMPOSITION OF VEGETABLES.

	Water.	Nitro- genous Matter. ³	Fat.	Carbo- hydrates.	Mineral Matter.	Cellu- lose.	Fuel Value per lb.
							Calories.
Cabbage	89·6	1·8	0·4	5·8	1·3	1·1	165
" (cooked)	97·4	0·6	0·1	0·4	0·13	1·3	
Cauliflower (head)	90·7	2·2	0·4	4·7	0·8	1·2	175
Sea-kale	93·3	1·4	—	3·8	0·6	0·9	
" (cooked) .. .	97·95	0·4	0·07	0·3	0·2	1·1	
Spinach	90·6	2·5	0·5	3·8	1·7	0·9	120

¹ Chlorophyll itself is of no nutritive value, but leaves the body hardly changed.

² Even of what nitrogenous matter is present only about half is in the form of protein.

³ Probably only about half of the nitrogenous matter consists of protein

COMPOSITION OF VEGETABLES—*continued*.

	Water.	Nitro- genous Matter ¹	Fat.	Carbo- hydrates.	Mineral Matter.	Cellu- lose.	Fuel Value per lb.
							Calories
Vegetable marrow	94.8 *	0.06	0.2	2.6	0.5	1.3	
Vegetable marrow (cooked)	99.17	0.09	0.04	0.2	0.05	0.37	
Brussels sprouts ..	93.7	1.5	0.1	3.4	1.3	—	95
Tomatoes	91.9	1.3	0.2	5.0	0.7	1.1	105
" (cooked)	94.07	1.0	0.2	0.1	0.76	1.5	
Greens	82.9	3.8	0.9	8.9	3.5	—	275
Lettuce	94.1	1.4	0.4	2.6	1.0	0.5	105
" (cooked)	97.2	0.5	0.16	0.5	0.4	0.9	
Leeks	91.8	1.2	0.5	5.8	0.7	—	150
Celery	93.4	1.4	0.1	3.3	0.9	0.9	85
" (cooked)	97.0	0.3	0.06	0.8	0.5	1.0	
Turnip cabbage ..	87.1	2.6	0.2	7.1	1.5	1.3	145
Rhubarb	94.6	0.7	0.7	2.3	0.6	1.1	105
Macedoine (tinned)	93.1	1.4	—	4.5	1.0	—	110
Watercress	93.1	0.7	0.5	3.7	1.3	0.7	
Cucumber	95.9	0.8	0.1	2.1	0.4	0.5	70
" (cooked)	97.4	0.5	0.02	0.7	0.2	0.9	
Asparagus ²	91.7	2.2	0.2	2.9	0.9	2.1	110
Salsify (cooked) ..	87.2	1.2	0.08	9.0	0.3	2.2	
Endives	94.0	1.0	—	3.0	0.8	0.6	
Savoys	87.0	3.3	0.7	6.0	1.6	1.2	
Red cabbage	90.0	1.8	0.19	5.8	0.7	1.2	
Sauerkraut	91.0	1.4	0.7	2.8	1.7	0.9 (acids 1.26)	

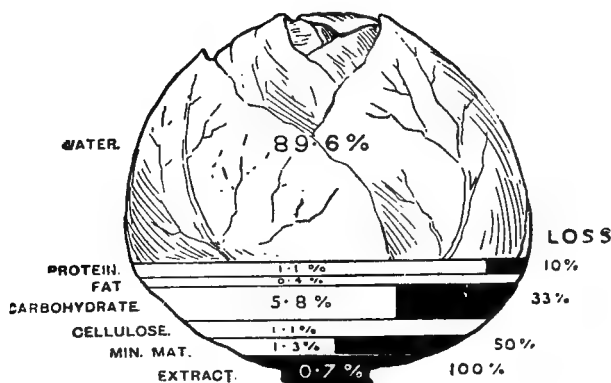


FIG. 22.—PERCENTAGE COMPOSITION OF A CABBAGE, AND LOSS OF EACH CONSTITUENT ON BOILING.

¹ Probably only about half of the nitrogenous matter consists of protein.² Asparagus contains asparagin, which confers upon it slight diuretic properties. The characteristic odour in the urine which follows the eating of asparagus is due to a volatile sulphur compound which is produced from it in the intestine.

These facts regarding the composition of green vegetables will be better realized by a study of Figs. 22 and 23. The former represents the composition of a cabbage, *i.e.*, a typical green vegetable, while the latter depicts the ingredients of a cucumber, which is a type of one of the least nutritive of this class of foods.

The effect of cooking upon green vegetables is still further to reduce their already poor stock of nutrients. They gain water, and lose part of their carbohydrate and protein, much of their mineral

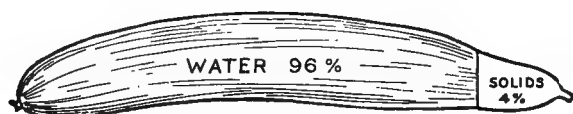


FIG. 23.—PERCENTAGE COMPOSITION OF A CUCUMBER.

matter, and nearly the whole of their non-protein nitrogenous constituents. For example, a cabbage loses by boiling 30 per cent. of its total solids, this being made up of about half of the total mineral matter, one-third of the carbohydrate, the whole of the non-protein nitrogen, and 5 to 10 per cent. of the protein (see Fig. 22).

The amount of water gained by some of the commoner vegetables as the result of cooking is shown in the following table:¹

GAIN OF WATER ON COOKING VEGETABLES.

	Percent. of Water in Raw State.	Percent. of Water after Cooking.	Increase.
Parsnips	82.0	97.2	15.2
Artichokes	80.0	91.6	11.6
Cabbage	89.0	97.5	8.5
Spinach	90.0	98.0	8.0
Cauliflower	90.8	96.4	5.6
Sea-kale	93.3	97.9	4.6
Vegetable marrow	94.8	99.1	4.3

The next table shows the amount of carbohydrate contained in some of the commoner vegetables, and (in some cases) the loss on boiling:²

	Raw (per cent.).	After Boiling and Straining (per cent.).
Cabbage turnip (young)	3.09	2.43
Cauliflower	2.10	1.40
Spinach	2.97	0.85
Winter cabbage	6.75	3.20
Asparagus	—	1.6
Savoys	2.7	—

¹ From analyses by Katherine J. Williams, *Journ. of Chem. Soc.*, 1892, lxi, 226. See also the same author's 'Losses and Other Chemical Changes in Boiling Vegetables,' *Chemical News*, March 31, 1916.

² From analyses by Kraus, *Zeit. f. Diät. und Physik. Therap.*, 1898, i, 69.

The deficiency of fat in vegetables is often made up by the addition of butter or oil, in the course of preparation for the table. Vegetables may thus be made an important vehicle for conveying fat into the body. The proportion of fat which some vegetables can take up without being overloaded is as follows :¹

100 parts of potato purée	can take up	50 parts of fat
" " boiled potato	" "	40-50 "
" " baked "	" "	" "
" " red cabbage	" "	40 "
" " savoy cabbage	" "	32 "
" " cabbage lettuce	" "	24 "
" " potato soufflé	" "	20 "
" " fried potatoes	" "	15 "

Vegetables, as a whole, are **not easily digested** by the stomach. Five and one-third ounces of cabbage require three hours. Cauliflower, it is worth knowing, is much the most easily digested of all of them. Five and one-third ounces of it require only two and a quarter hours.

In the intestine also vegetables are difficult to deal with. The reason for this is their bulk and the amount of cellulose which they contain. Gases are produced by the action of organisms on the cellulose, and from this flatulence is apt to result. Fermentation is specially apt to occur when the vegetables are a little stale. To be wholesome they should always be eaten as fresh as possible.

The **absorption** of the nutritive constituents of most vegetables is also rather defective. They constitute one of the few forms of food from which even starch is not completely absorbed. The average waste on green vegetables is approximately as follows (Rubner):

Dry substance ..	15.0 per cent. lost	Carbohydrates ..	15.4 per cent. lost
Protein ..	18.0 " "	Mineral constituents	22.8 " "

When one realizes that green vegetables are poor in nutrients to start with, that they become still poorer as the result of cooking, and that even of the remnant which reaches the intestine a large part escapes absorption, one will readily understand that, considered as foods, they are of **very low nutritive value**. Indeed, it may be said that green vegetables are only of use in the diet for three reasons. First, they supply **ballast** to the intestine; the indigestible residue which they leave is a stimulus to the intestinal movements. Hence their special value in constipation. Secondly, they are a **valuable source of mineral salts**. The most abundant of these are compounds of potash, which have an alkaline reaction, and help to keep the blood supplied with alkali and to lower the acidity of the urine. It is probably owing to their richness in alkaline salts that the

¹ From analyses by Kraus, *Zeit. f. Diät. und Physik. Therap.*, 1898, i. 69.

use of green vegetables is helpful in some diseases of the skin. Thus, Clement Dukes points out that he has several times seen epidemics of eczema result from a deficiency of green vegetables in the diet ('School Diet,' p. 103). For the same reason the free use of green vegetables should be recommended to patients who suffer from gravel. Some vegetables, such as rhubarb, contain a good deal of oxalic acid, and indeed a few cases of apparent oxalic acid poisoning have occurred from the eating of cooked rhubarb leaves.¹ These should be avoided in cases of gravel. The sour taste of tomatoes is due to citric acid, not to oxalic, as is often stated. Asparagus and onions are the only vegetables which contain appreciable amounts of uric acid-forming bodies. Green vegetables are also valuable sources of iron in the diet. The value of the mineral ingredients of vegetables, however, will be dealt with more fully in a subsequent chapter. Lastly, green vegetables are an important source of the mysterious substances called **vitamins** (p. 18). It is to the presence of these that the curative influence of fresh vegetables in scurvy is due, and there is no doubt that some of the benefits derived from their use in health are to be ascribed to the same cause.

Fruits.

The fruit is not of direct benefit to the plant. It is intended as a bait to attract birds or insects, and so insure the liberation or transportation of the seed. Hence the æsthetic qualities pre-

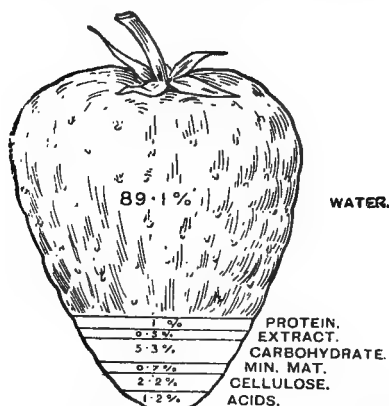


FIG. 24.--PERCENTAGE COMPOSITION OF A STRAWBERRY.

dominate in fruit rather than the strictly nutritive, and we eat them more for the sake of their sweetness and flavour than for the actual nourishment which they afford.

¹ For a criticism of these alleged occurrences, however, see Harrington Sainsbury, 'Rhubarb Leaves and Flowers as a Vegetable,' *Lancet*, July 17, 1917.

The general composition of fresh fruit is something like this :

Water	85 to 90 per cent.	Carbohydrates ..	5½ to 10½ per cent.
Protein	0.5 ..	Cellulose	2½ ..
Fat	0.5 ..	Mineral matters ..	0.5 ..

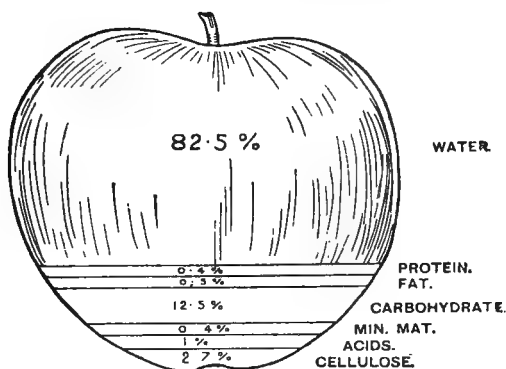


FIG. 25.—PERCENTAGE COMPOSITION OF AN APPLE.

The composition of individual members of the group is shown in the following table, and a study of the graphic representation of some typical fruits will illustrate it (Figs. 24, 25, and 26).

AVERAGE COMPOSITION OF FRUITS (EDIBLE PORTION).

	Water.	Protein.	Ether Extract.	Carbo- hydrates.	Ash.	Cellu- lose.	Acids.
Apples	82.5	0.4	0.5	12.5	0.4	2.7	1.0
.. (dried) ..	36.2	1.4	3.0	49.1	1.8	4.9	3.6
Pears	83.9	0.4	0.6	11.5	0.4	3.1	0.1
Apricots	85.0	1.1	?	12.4	0.5	—	1.0
Peaches	88.8	0.5	0.2	5.8	0.6	3.4	0.7
Greengages ..	80.8	0.4	—	13.4	0.3	4.1	1.0
Plums	78.4	1.0	?	14.8	0.5	4.3	1.0
Nectarines ..	82.9	0.6	?	15.9	0.6	—	—
Cherries	84.0	0.8	0.8	10.0	0.6	3.8	1.0 to 1.5 (Stutzer)
Gooseberries ..	86.0	0.4	—	8.9	0.5	2.7	1.5
Currants (red, black and white) ..	85.2	0.4	—	7.9	0.5	4.6	1.4
Strawberries ..	89.1	1.0	0.5	6.3	0.7	2.2	1.0 to 1.2
Whortleberries (=							
Blueberries or Bil-							
berries)	76.3	0.7	3.0	5.8	0.4	12.2	1.6
Blackberries ..	88.9	0.9	2.1	2.3	0.6	5.2	—
Raspberries ..	84.4	1.0	?	5.2	0.6	7.4	1.4
Cranberries ..	86.5	0.5	0.7	3.9	0.2	6.2	2.0 to 2.5
Mulberries ..	84.7	0.3	—	11.4	0.6	0.9	1.8

AVERAGE COMPOSITION OF FRUITS (EDIBLE PORTION)—
continued.

	Water.	Protein.	Ether Extract	Carbo- hydrates.	Ash.	Cellu- lose.	Acids.
Grapes	79'0	1'0	1'0	15'5	0'5	2'5	0'5
Melons	89'8	0'7	0'3	7'6	0'6	1'0	
Water-melons ..	92'9	0'3	0'1	6'5	0'2		
Bananas	74'0	1'5	0'7	22'9	0'9	0'2	
Oranges	86'7	0'9	0'6	8'7	0'6	1'5	1'0 to 2'5
Orange-juice ..	85'0	—	—	10'8	—		1'93
Lemons	89'3	1'0	0'9	8'3	0'5		
Lemon-juice ..	90'0	—	—	2'0	0'4	—	7'0 (citric acid)
Pineapples ..	89'3	0'4	0'3	9'7	0'3		
Pomegranates ..	76'8	1'5	1'6	16'8	0'6	2'7	
Dates (dried) ..	20'8	4'4	2'1	65'7	1'5	5'5	
Figs (dried) ..	20'0	5'5	0'9	62'8	2'3	7'3	1'2
„ (fresh) ..	79'1	1'5	—	18'8	0'6		
Prunes (dried) ..	26'4	2'4	0'8	66'2	1'5	—	2'7
„ (fresh) ..	80'2	0'8	?	18'5	0'5		
Currants (dried) ..	27'9	1'2	3'0	64'0	2'2	1'7	
Raisins	14'0	2'5	4'7	74'7	4'1		
Olives	67'0	2'5	17'1	5'7	4'4	3'3	
Rhubarb Stalks ..	94'4	0'6	0'7	2'5	1'1	0'7	

The composition of edible parts only is represented. Where cellulose is not given it is included with carbohydrates.

It will be observed that the only nutritive element of any importance in fruit is the **carbohydrate group**. As a general rule, about half to three-quarters of the total carbohydrates in a fruit consist of sugar. The particular variety is that known as fruit-sugar, or, in chemical language, *lævulose*; but some fruits, *e.g.*, apples, apricots, and pineapples, contain a considerable amount of cane-sugar as well. It is of some importance to remember this, for *lævulose* is certainly more easily assimilated by diabetics than other sugars are, so that fruits may often be allowed in mild cases of that disease with impunity. The total amount of sugar contained in some typical fruits is shown in the following table:¹

	Total Sugar (per cent.).		Total Sugar (per cent.).
Hot-house grapes ..	17'26	Preserved apples ..	6'25
Preserved „ ..	16'50	Raspberries	7'23
Figs (fresh) „ ..	11'55	Oranges	8'58
Cherries	10'00	Apricots	8'78
Preserved pears ..	8'78	Pineapples	13'31
Fresh pears	7'84	Plums	1'99
White currants ..	6'40	Lemons	1'47
Strawberries	5'86		

The remainder of the carbohydrates is made up of vegetable gums. Many of these seem to belong to that group of 'pectin bodies' to which reference has already been made (p. 163). In the

¹ Analyses by Buignet (quoted by König).

course of ripening, some of them seem to be converted into the corresponding sugar—**pentose**, the nutritive value of which must be regarded as very doubtful. When subjected to boiling, the gums of many fruits yield a jelly, the production of which is familiar in the process of making preserves.

The amount of **cellulose** varies greatly in different fruits. It is always lessened by the process of cultivation—witness the difference between a crab apple and a Newtown pippin—and it diminishes also, by a sort of natural digestion, during the ripening of the fruit.

The **mineral constituents** of fruits are of considerable importance. They consist mainly of potash united with various vegetable acids, such as tartaric, citric, and malic. These have an agreeable acid flavour, but when burnt up inside the body are converted into the corresponding carbonate, and so help to render the blood more alkaline and the urine less acid. Thus, 1 fluid ounce of lemon-juice contains 45 grains of citric acid and saturates $45\frac{1}{2}$ grains of bicarbonate of soda. As the fruit ripens, these vegetable acids diminish to some extent, and it is to this fact, coupled with an increase in the amount of sugar present, that the sweetness of ripe as compared with unripe fruit is due. The earthy salts are but poorly represented among the mineral ingredients of fruits, and for this reason the free use of fruit in place of cereals has been recommended by some writers to persons suffering from atheroma.

The **odour and flavour** of fruits are due to the presence of very small quantities of ethereal bodies which sometimes elude chemical investigation. In many cases, however, we have been able to obtain (from coal-tar, too, of all sources) artificial products which have precisely the same flavour as many fruits. These products form the basis of the different fruit flavourings and essences sold in the shops. Although of no nutritive value, the flavouring substances contained in fruits are by no means to be despised as stimulants to the appetite and aids to digestion.

Cooking renders most fruits more digestible by softening their cellulose, and it also, as we have seen, converts the gums into a gelatinous form. But these changes are not brought about without a good deal of loss. The loss affects all the ingredients of the fruit. The following instances show the exact figures for the carbohydrates:¹

¹ From analyses by Kraus, *Zeit. f. Diät. u. Physik. Therap.*, 1898, i 69.

Raw apples ..	11.7 per cent.	Pears once boiled ..	6.6 per cent.
Apples once boiled	7.3 "	" twice "	5.9 "
" twice "	6.1 "	Raw peaches ..	9.5 "
Raw pears ..	10.1 "	Peaches once boiled	1.8 "

Where, as is usually the case, the fruit is cooked by stewing and the juice eaten along with it, this effect of cooking is of no moment.

The **digestibility of fruit** in the stomach and intestine is dependent largely on the nature of the fruit and its degree of ripeness. Five and a third ounces of raw ripe apple (one large or two small apples) require about three hours and ten minutes for its digestion by the stomach. On the other hand, if the fruit be unripe and the amount of cellulose consequently greater, digestion may be much more prolonged. The excess of acids present in unripe fruit causes the latter to be irritating to the intestine, and a frequent originator of diarrhoea and colic. If, however, the cellulose and acids are contained in more moderate quantity, as in ripe fruit, the gentle stimulation which they exert on the intestinal wall may be very useful. Hence it is that stewed fruit is so serviceable an addition to the diet in sluggish action of the bowels.

There have been few experiments made to test the degree to which fruit is absorbed by the human intestine, but one may expect that the protein will be absorbed to about 90 per cent., the fats to 85 per cent., and the carbohydrates to 95 per cent., if the conditions be reasonably favourable.

From a nutritive point of view fruits may be artificially divided into the two groups of **flavour-fruits** and **food-fruits**. In the former one would include all fruits which contain more than 80 per cent. of water; in the latter, all fruits or fruit preparations which have more than 20 per cent. of solids.

The only claim of the members of the first group to be regarded as foods is that they contain a small amount of sugar in a pleasant but rather bulky form.¹ They are chiefly eaten for the sake of their pleasant flavour. Their richness in water makes them more adapted to the requirements of the inhabitants of warm countries than for use in northerly latitudes, and one finds that if they are freely represented in the diet less water requires to be consumed.

Grapes stand intermediate between the two groups, for their juice contains an amount of sugar which varies from 10 per cent. in the poorer up to 30 per cent. in the richer varieties. In the so-called **grape-cure**, from 1 to 8 pounds of grapes are taken daily in divided quantities, and between meals. If the rest of the diet is sufficient, the patient may gain weight on this regimen, while the grape-juice,

¹ They also contain the antiscorbutic vitamin.

owing mainly to the organic acids which it contains, acts as a mild laxative and diuretic, and at the same time diminishes slightly the acidity of the urine. In this, as in all similar 'treatments,' much of the credit of the results attained must be put down to the circumstances under which the 'cure' is carried out, for the patient is expected to gather the grapes for himself, and doing this entails a certain amount of exercise in the fresh air. It is chiefly in cases of so-called 'abdominal plethora,' *i.e.*, the results of habitually eating too much and taking too little exercise, that benefit has been

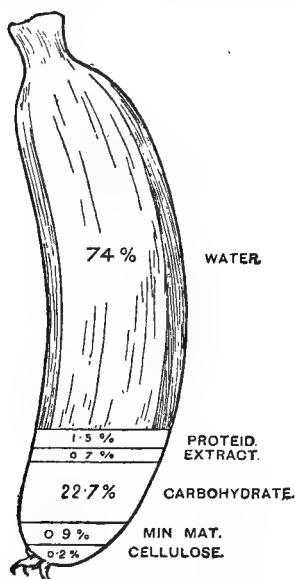


FIG. 26.—PERCENTAGE COMPOSITION OF A BANANA.

observed from such a course of treatment, but it is also useful in some cases of chronic bronchial catarrh.

Mostelle is an unfermented grape-juice preserved by pasteurization. It contains about 25 per cent. of grape-sugar, and is a useful food-beverage, especially in fevers.

The **food-fruits**, on the other hand, are not to be despised as sources of real nutriment. Of this group the **banana** is a good example. In the fresh state this fruit contains a fair amount of carbohydrate and an appreciable amount of protein as well, while bananas dried in the sun and sprinkled with sugar, a form in which they have recently been imported, compare favourably with dried

figs in nutritive value, and are a pleasant substitute for the latter at dessert.

In its ordinary form, however, the banana is too bulky to be able to serve as the main constituent of a healthy diet. Assuming that an average sized specimen weighs 45 grammes or $1\frac{3}{8}$ ounces (without the husk), it would require about eighty of these to yield the amount of energy required daily, and nearly double that number to supply the requisite amount of protein.¹ No wonder, then, that in tropical countries, where the banana is largely eaten, the inhabitants are apt to show an undue abdominal development.

The unripe banana is dried and used to produce **banana meal or flour**. A sample of such a flour had the following composition :

				<i>Banana Flour.</i>	<i>Wheat Flour.</i>
Moisture	..	..	..	13·0 per cent.	13·8 per cent.
Protein ..	..	..	..	4·0 ..	7·9 ..
Fat ..	..	..	..	0·5 ..	1·4 ..
Carbohydrates..	..	..	..	80·0 ..	76·4 ..
Mineral matter	..	..	..	2·5 ..	0·5 ..

I have placed alongside of it the composition of good wheat flour, compared with which the banana-meal is rich in carbohydrates and mineral matter, but very poor in protein. If rice, on the other hand, had been taken for comparison, it would have been found that banana flour was about equal to it in nutritive value.

Bananina is a proprietary food obtained from the banana by a special process after the fibrous matter has been extracted, and is designed for the use of infants and invalids. For an analysis of it, see p. 468. It consists chiefly of starch, but is stated to be easily digested.

Banana flour can be used to make a sort of bread, and it is said to be easy of digestion. Two pounds of such flour and a quarter of a pound of salt meat or fish is stated to form the daily allowance for a labourer in tropical America (Johnston).

Another advantage of the banana is the cheapness with which it can be produced. A given area of ground devoted to its cultivation

¹ These quantities have been calculated from European dietary standards, and represent the amount of energy and protein required by a man in this country. On the Gold Coast, however, as Mr. C. G. Moore informs me, the natives eat about eight plantains (the equivalent of about sixteen bananas) daily, supplemented occasionally by a little dried fish, and on this diet they manage to perform a fair amount of work.

will yield a larger food return than if it were planted with potatoes. The bread-fruit, the sugar-cane, and the chestnut, however, exceed the banana in their food yield per acre.

Surpassing even the banana in nutritive value is the group of **dried fruits**, which includes such examples as the **date** and the **raisin**. The former, indeed, is as much a staple article of diet to the Egyptian as rice is to the Hindu, but the carbohydrate of rice is mainly in the form of starch, whereas in the date it is almost solely present as sugar. 'A half-pound of dates and half a pint of milk makes an ample and satisfying meal for a person engaged in sedentary labour' (Densmore).

The **fig** is another valuable member of this group. Dried figs contain about 50 per cent. of sugar and 3.5 per cent. of protein. Weight for weight, they are more nourishing than bread, and a pint of milk and 6 ounces of dried figs makes a good meal. One and a half pounds of them yield 400 grammes of carbohydrate, or four-fifths of the total amount of that nutritive ingredient required daily.

AVERAGE COMPOSITION OF DRIED FRUITS (EDIBLE PORTION).

		Water.	Protein.	Ether Extract.	Carbo- hydrates.	Cellu- lose.	Ash.	Calorie Value per Pound.
Dates	... ..	15.4	2.1	2.8	74.6	3.8	1.3	1,615
Figs	.. ..	18.8	4.3	0.3	68.0	6.2	2.4	1,475
„ (stewed	.. ..	56.5	1.2	0.3	40.9		1.1	785
Prunes	.. ..	22.3	2.1	—	71.2	2.1	2.3	1,400
„ (stewed)	.. ..	76.6	0.5	0.1	22.3		0.5	430
Raisins	.. ..	14.6	2.6	3.3	73.6	2.5	3.4	1,605

Nuts.

Nuts differ very markedly from the fruits which we have been considering, in that they are of very high nutritive value. Bulk for bulk, indeed, dry nuts are amongst the most nutritive foods which we possess. Their **general composition** is roughly as follows:

Water ..	4 to 5 per cent.	Carbohydrates ..	9 to 12 per cent.
Protein ..	15 „ 20 „	Cellulose ..	3 „ 5 „
Fat ..	50 „ 60 „	Mineral matter ..	1 per cent.

A graphic representation of a typical specimen of the group, the walnut, is shown in Fig. 27.

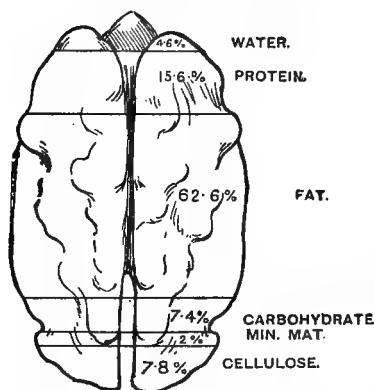


FIG. 27.—PERCENTAGE COMPOSITION OF A WALNUT.

It will be observed that fatty matter predominates very largely in the composition of nuts. No other vegetable substance is so rich in fats as these. Advantage has been taken of this to prepare from nuts various fatty preparations which are used as cheap and efficient substitutes for ordinary butter in the kitchen. Amongst these are the commercial preparations known as 'Albene,' 'Nucoline,' 'Vegsu,' or 'vegetable suet,' 'Nut Butter' and 'Nuttolene,' also 'Cocos Butter,' 'Cocoleum,'

and 'Cocolardo.' There is every reason to believe that these are equal in nutritive value to ordinary butter, whilst they are decidedly more economical. 'Albene' costs 9d. per pound, and 10 ounces of it are said to go as far as 1 pound of butter. 'Nucoline' costs 6d. per pound, and 4 pounds of it are stated to be equivalent in cooking operations to 6 pounds of butter. 'Nut Butter' and 'Nuttolene' contain protein as well as fat, and are therefore to be compared to cream rather than to ordinary butter.

Unfortunately, nuts are **not readily digested** in the stomach. This is due in part to their richness in fat, and partly also to their containing a high proportion of cellulose, which forms a dense and compact framework throughout the structure of the nut. By thorough mastication, the latter difficulty can be overcome to some extent, but it is still more efficiently dealt with by artificial grinding and cooking. Various preparations derived from nuts, in which this mechanical cause of difficulty in their digestion has been to a large extent overcome, are now in the market. Best known of these are the 'Fromm's Extract,' and the various preparations of the Sanitas Nut Food Co. ('Nuttose,' 'Bromose,' 'Nutmeal,' and 'Malted Nuts,' etc.).

Fromm's Extract consists of nuts which have been crushed, and from which the excess of cellulose and oil have been removed. The preparation is then cooked under special conditions, which develops in it a flavour not unlike that of meat. It has the following composition :

FROMM'S EXTRACT.

Water	..	..	25.3 per cent.	Carbohydrates and	
Protein	..	..	21.9	cellulose	.. .. 8.3 per cent.
Fat	..	..	31.6	Mineral matter	.. 12.8

There can be no doubt that this is a preparation of high nutritive value. It costs, however, 3s. 6d. per pound.

The following is the composition of **malted nuts** :

Water	..	..	4.5 per cent.	Maltose	.. .. 49.3 per cent.
Protein	..	..	23.6	Mineral matter	.. 2.2
Fat	..	..	20.4		

But few experiments have been made on the **absorbability** of nuts. In one which was carried out in America,¹ and in which the subject of experiment lived solely on a diet of fruit and nuts, it was found that 82.5 per cent. of the protein, 86.9 per cent. of the fat, and 96 per cent. of the non-nitrogenous matters were absorbed. This result compares favourably with the absorption of an ordinary mixed diet except that it shows a rather greater waste of protein, and shows that it is quite possible, for long periods at any rate, to supply the requisite protein and energy from a diet made up of selected fruits and nuts.

The **nutritive value of nuts** is no doubt extremely high, and when suitably prepared they may form substitutes for meat to a considerable extent, for they resemble the latter in containing much protein and fat in small bulk.² They are an even more concentrated food than cheese, and should rather be used as part of the ordinary diet than as a supplement to an otherwise large meal. Thirty large walnuts (weighing, without the shells, 100 grammes) would contain as much fat as $2\frac{3}{4}$ pounds of moderately lean beef, but $2\frac{3}{8}$ ounces of such beef would be equal to them in protein. It would be necessary to consume about 700 walnuts in order to obtain the necessary amount of protein required by the body every day.

A cocoanut weighing $1\frac{1}{4}$ pounds contains $\frac{1}{4}$ pound of fat. Its price is about 2d., so that as a source of fat it is equivalent to butter at 8d. the pound.

Of all the members of this class of foods, the **chestnut** is probably of the greatest general value as an article of diet. This is due to its containing a high proportion of carbohydrates along with much protein and fat, as is shown in the following recent analyses :

¹ 'Nutrition Investigations among Fruitarians and Chinese,' U.S. Department of Agriculture, Office of Experiment Stations, Bull. No. 107, 1901. For more recent experiments, which, however, yielded substantially the same results, see 'Nuts and their Uses as Foods,' Farmers' Bull. No. 332, 1908.

² Not only are nuts very rich in proteins, but these proteins are of high 'biological value' (see Cajori, *Journ. of Biol. Chem.*, 1920, 43, 583).

COMPOSITION OF CHESTNUTS.¹

		H ₂ O.	N Matter.	Fat.	Carbo- hydrates.	Cellulose.	Ash.	Acidity.
Mini-	Normal	52.80	2.01	0.45	31.54	0.74	0.57	0.059
mum	Dried ..	0.00	4.45	1.17	82.17	1.76	1.24	0.164
Maxi-	Normal	62.60	4.31	1.73	40.74	1.36	1.22	
mum	Dried ..	0.00	11.05	3.74	88.61	3.29	3.06	

Roasted chestnuts have 40 per cent. water. Those cooked by boiling have 72 per cent.

An economic point in favour of chestnuts also is the fact that a given area of ground produces perhaps the maximum amount of human food when planted with chestnut-trees.

The great value of the chestnut has been fully recognised by the poorer peasantry of Central France. During the autumn and winter they often make two meals a day from it alone. The nuts are prepared by removing the outside shell, blanching, and then steaming; salt and milk are added when they are eaten. Sometimes they are ground after blanching, and the meal made into flat cakes.

The almond is another very valuable form of nut, being specially noteworthy for the large amount of nitrogenous matter which it contains. It has the further advantage of being compact and portable. 'No man,' it has been said, 'need starve on a journey who can fill his waistcoat pocket with almonds.'

Owing to its poverty in carbohydrates, the almond is largely employed in the manufacture of diabetic breads. The detailed composition of the commoner varieties of nuts is exhibited in the following table:

COMPOSITION OF NUTS (EDIBLE PORTION).

			Water.	Protein.	Fat.	Carbo- hydrates.	Cellu- lose.	Mineral Matter.
Chestnuts (fresh)	..	..	38.5	6.6	8.0	45.2		1.7
" (dried)	..	..	5.8	10.1	10.0	71.4		2.7
Walnuts (fresh)	..	..	44.5	12.0	31.6	9.4	0.8	1.7
" (dried)	..	..	4.6	15.6	62.6	7.4	7.8	2.0
Filberts and hazels (fresh)	..	..	48.0	8.0	28.5	11.5	2.5	1.5
" (dried)	..	..	3.7	14.9	66.4	9.7	3.2	1.8
Sweet almonds	..	..	6.0	24.0	54.0	10.0	3.0	3.0
Pistachio kernels	..	..	7.4	21.7	51.1	14.0	2.5	3.3
Cocoonut (fleshy part)	..	..	46.6	5.2	35.9	8.4	2.9	1.0
" (dried)	..	..	3.5	6.0	57.4		31.8	1.3
" (milk)	..	..	90.3	0.5	—		9.0	—
Hickory nuts	..	..	6.0	15.0	65.0		12.0	2.0
Brazil nuts	..	..	5.0	17.0	67.2		7.0	4.0
Pea nuts (kernels)	..	..	9.3	27.9	42.0		18.7	2.1

¹ Balland, ref. *Analyst*, 1897, p 216.

Fungi.

The edible fungi are popularly spoken of as mushrooms, and the inedible ones as toadstools. There is really, however, no such division, for all the larger fleshy fungi are toadstools, and probably most of them are edible. The word 'mushroom' has therefore only the practical convenience of distinguishing the best-known edible fungi met with in commerce.

There are about 1,400 species of toadstools met with in this country, and of these about a hundred are known to be edible, while not more than thirty have been definitely proved to be poisonous. There are probably a great many more edible varieties, but the only way of finding out whether they are so or not is by trying—a mode of experiment which is somewhat risky. But our ignorance in this respect need not be a matter of regret, for even although many more toadstools should be found to be harmless, yet they are probably not worth the eating.

The poisonous properties of fungi are due to the presence in them of alkaloids. The nature of these differs in the different species, so that the symptoms of toadstool-poisoning are varied. The genus *Amanita*, most of which are very dangerous, contains an alkaloid 'Amanita toxin,'¹ which acts as an irritant to the stomach and bowels, and also paralyzes the nervous system. This poison is peculiar in that it does not exert its effects for some hours after the fungus has been swallowed, so that at first the patient feels perfectly well. It is, however, extremely potent, so that a very small portion of such a fungus may prove fatal. The alkaloid found in the poisonous examples of *Russula* and *Lactarius* is purely irritant in its effects, and induces vomiting and diarrhoea, thus leading to the discharge of the fungus, and bringing about its own cure. The symptoms, too, follow immediately upon the eating of the fungus, and without any delay. The *Agaricus muscarius* contains the alkaloid muscarin, which produces symptoms very much resembling those of cholera. The Czar Alexis lost his life by eating it.

It is not easy to lay down definite rules for the recognition of the harmless fungi, while, unfortunately, some of the most dangerous are also those of commonest growth. Certain general indications it is always safe to observe. Thus, all fungi should be avoided when they are overripe, or when they have been attacked by slugs. Those that soften easily are usually dangerous, and the same is true of fungi which grow in dirty situations, such as dunghills, for this

¹ See Ford ('A Consideration of the Poisons of *Amanita Phalloides*'), *Brit. Med. Journ.*, 1906, ii. 1541.

plant has a great tendency to absorb poisons from the medium on which it happens to be growing. Lastly, all those which have a disagreeable smell or taste should certainly be rejected.

The fungus-eater's safest ground is unquestionably amongst the *Boletus* family. The distinguishing mark of these fungi, as opposed to the *Agarici* is that they have tubes under the cap instead of gills. Of the forty-nine native species of this family, most are edible, and many quite excellent. But there are exceptions, one or two members being virulently poisonous. There need not, however, be any difficulty in distinguishing these, for all the safe ones are characterized by being yellow beneath the cap. To this rule there is only one exception, and it is easily told by its scarlet stem. All those that are red or pink or orange or brown beneath the cap should be avoided. It is well also to discard all those which change colour on cutting or bruising.

The *Boletus edulis* occurs abundantly in beech woods, especially in the South of England. It has a light brown cap, the under part of which is first white and then yellow-green, with a thickish pale brown stem, surmounted by a fine white network. This network is the best feature by which to distinguish it from its congeners. It is in best edible condition when the under surface is yellowish.

Belonging to a different family (the Hydnei, or teeth-bearing fungi) is the *Hydnum repandum*—the urchin of the wood. It is of a buff white colour, and is easily recognised by the long unequal spines beneath its cap. It is amongst the most delicate of toadstools, having a slight flavour of oysters. It is best in the young and fresh state, and is largely employed as food in Belgium, Austria, and France. The *Agaricus* family includes a large number of edible fungi, the best known of which is the common mushroom (*Agaricus campestris*). Another favourite is the *Agaricus gambosus*, or St. George's mushroom, which is found in spring and early summer, growing on downs and pastures, often in immense fairy-rings. Its stem is stout and solid, and the gills yellowish-white and much crowded together. It has a strong odour of fresh meat, which is so powerful that workmen employed to root out the fungus are said to have been so overcome by the odour as to be compelled to desist (Cook). It is better eating than the common mushroom.

One of the best of all is the *Paxillus giganteus*, which is found in August and September. It is firm in texture and of a dingy white colour with yellow stains on the stem. It is easily identified by its fine, creamy white gills and its broad inrolled disc.

The *Lactarius deliciosus* and the *Cantharellus Cibarius* (chantrelle)

belong to different groups. The former, as its name implies, is one of the nicest of all edible fungi. It is not difficult to recognise, but is apt to be attacked by a reddish parasitic fungus, and in that state is dangerous. It is of an orange colour with a yellowish, milky juice, and grows abundantly in fir plantations. The chanterelle is found in large numbers in most of our woods in autumn. It is orange yellow both within and without, and has a pleasant smell of ripe apricots. It has a delightful flavour, and one writer goes the length of saying that if properly prepared 'it would arrest the pangs of death!'

The common morel (*Morchella esculenta*) and the truffle (*Tuber cibarium*) are both much-prized fungi. The former grows in England, but is usually imported from abroad in a dried state, and fetches a high price. The truffle is an underground fungus which grows in dry soils. In England it is chiefly found in Wiltshire, Hampshire, and Kent. The black variety is most esteemed. Both morels and truffles are chiefly valued for their delicate flavour, and are common constituents of seasonings and sauces. Though usually eaten dried, they are very much better when fresh.

The chemical composition of the commoner edible fungi is shown in the following table:

COMPOSITION OF FUNGI.¹

	Mushroom (<i>Agaricus campestris</i>).	Chanterelle (<i>Cantharellus cibarius</i>).	Truffle (<i>Tuber cibarium</i>).	Edible Boletus (<i>Boletus edulis</i>).	<i>Lactarius deliciosus</i> .
Moisture	93.7	90.93	73.0	84.19	89.08
Amides, etc.	1.3	0.64	1.4	2.6	0.91
Proteins	2.2	1.19	6.1	3.7	1.88
Fat	0.3	0.64	0.6	0.4	0.54
Carbohydrates	1.2	5.09	6.02	4.65	4.49
Cellulose	1.1	0.33	6.4	0.74	0.32
Mineral matter	0.3	1.20	2.0		

The following analysis of the solids and nitrogenous matter in tinned French mushrooms is given by Saltet:²

	Dry Substance.	Total Nitrogen.	Percentage of N in Dry Substance.	Proportion of the Total N present.
Mushrooms	37.84	2.7	7.13	84.9
Fluid in tin	8.91	0.48 ³	5.39	15.1
Together	46.75	3.18	6.8	100.0

¹ Chiefly compiled from analyses by Stahl-Schröder, *Maly's Jahres-Bericht Thier-Chemie*, 1897, xxvii. 699. See also Lafayette B. Mendel, *American Journal of Physiology*, 1898, i. 225.

² *Archiv. f. Hygiene*, 1885, iii. 443.

³ Probably mostly in form of amides.

It will be observed that as a class they contain but little dry substance. Of this, a comparatively large amount is nitrogenous matter, the remainder being chiefly made up of carbohydrates. The older fungi contain more nitrogen than the younger plants, and those which are cultivated are richer than those which grow wild. It must not, however, be supposed that the nitrogenous matter of the fungi is all in a form available for nutrition. On the contrary, a large proportion of it is in the form of amides and other non-protein bodies. Indeed, a reference to the table will show that the actual amount of albuminoid matter which the fungi contain is, with the exception, perhaps, of truffles, by no means large at all.

It is probably to the amides and their allies that most of the peculiar flavour of the fungi is to be attributed.

Recent analyses¹ of the different forms of nitrogen present in some common fungi have yielded the following results :

	<i>Cantharellus Cibarius.</i>	<i>Boletus Edulis.</i>	<i>Lactarius Deliciosus.</i>	<i>Morchella Escutenta.</i>	<i>Agaricus Campestris.</i>
Total N	2·69	3·87	3·11	4·99	7·38
Protein N	2·29	2·73	2·51	4·18	4·89
'Extractive' N	0·40	1·14	0·60	0·81	2·49
Indigestible protein N	1·46	0·65	1·05	1·90	1·17
Digestible	0·79	2·10	1·41	2·19	3·64

Starch is not represented amongst the carbohydrates of the fungi. They contain instead a curious and rare sugar called trehalose (mycose)² and a substance termed mannite, which is the parent of a sugar named mannose. The nutritive value of both of these substances is unknown. There is some reason to believe that mannite, at least, is not easily assimilated.³ The fungi contain also a good deal of cellulose, which seems to differ somewhat from that found in most plants.

As a result of cooking fungi shrivel up considerably. This is due to coagulation of the contents of the cells, which shrink instead of bursting, as they probably would do if they contained starch. They lose, also, much of their non protein nitrogenous constituents, and with these much of their flavour. They also gain in water to some extent, so that a stewed mushroom contains only about 2 per cent. of solid matter.⁴

¹ Mendel, *Amer. Journ. of Physiolog.*, 1898, i. 225.

² Winterstein, *Zeit. f. Physiolog. Chem.*, 1899, xxvi. 438.

³ Jaffé, *Zeit. f. Physiolog. Chem.*, 1883, vii. 297.

⁴ See analysis by Katherine J. Williams, *Journ. of Chem. Soc.*, 1892, xi. 226.

Fungi are not easily digested in the stomach. This is matter of common knowledge. The difficulty is probably largely due to the amount of cellulose which they contain, and to the shrinkage and greater compactness which result from cooking. The pain and discomfort which they are apt to produce in the stomach have often been wrongly attributed to poisons, and in consequence fungi which are merely indigestible have been regarded as inedible. Recent experiments *in vitro* have amply confirmed their indigestibility.¹

The absorption of the fungi is also very imperfect. One observer² took large quantities of fresh mushrooms daily. He found that 19 per cent. of the dry substance and 33·7 per cent. of the protein escaped absorption. Another got even less favourable results,³ two-fifths of the protein being excreted unchanged. Artificial digestion outside the body has yielded similar results.⁴ On the other hand, as one would expect, the absorption is considerably better if the mushrooms are taken in the form of powder, but even in that case 29 per cent. of the protein was lost.⁵

On the whole, mushrooms and other fungi must be ranked with such substances as green vegetables, carrots and black-bread as amongst the wasteful foods.

The nutritive value of the fungi has been very much exaggerated. Thus, they have been described as vegetable beefsteaks; it has been pointed out that the Patagonians and natives of Terra del Fuego live largely upon them, and their more extensive use has been urged upon the poorer classes in this country. This is partly owing to the failure to recognise that about one-third of their nitrogenous matter is in a form which is useless for the purposes of nutrition, and partly to ignorance of the very imperfect degree to which such foods are capable of being absorbed. Further, the carbohydrates which the fungi contain must be regarded as of very uncertain nutritive value. The fungi cannot, therefore, be looked upon as foods of any greater value and importance than fresh vegetables, and when one considers the high price paid for many of them, such as truffles, they must be regarded as pure luxuries. This conclusion was arrived at as early as 1824 by Dr. Kitchiner, who stated in his 'Cook's Oracle' that he did not believe that mushrooms were really nutritious. Pereira expressed a similar opinion twenty years later. It only remains to

¹ Gane, *Food and Sanitation*, April 22, 1899.

² Saltet, *Archiv. f. Hygiene*, 1885, iii. 443.

³ Uffelmann, *Archiv. f. Hygiene*, 1887, vi. 105.

⁴ Mörner, *Zeit. f. Physiolog. Chem.*, 1886, x. 503.

⁵ Uffelmann, *Archiv. f. Hygiene*, 1887, vi. 105.

add that when eaten in large amount they rapidly produce a feeling of satiety, and this must always constitute a further obstacle to their taking serious rank as articles of diet.

Algæ.

This group includes the seaweeds, several varieties of which, *e.g.*, laver, dulse, etc., are occasionally used as foods. The only one which demands special consideration is **Irish** or **Carraigeen moss** (*Chondrus crispus*), which is not only sometimes used as an ordinary article of diet, but finds a place also among the dietetic resources of the sick-room. Irish moss comes into the market in a dried form, and has approximately the following composition (Church):

Water	..	..	..	..	18.8	per cent.
Nitrogenous matter	..	..	..	..	9.4 ¹	..
Mucilage, etc.	..	..	..	..	55.4	..
Cellulose	..	..	..	..	2.2	..
Mineral matter	..	..	..	..	14.2	..

Its chief constituent is the substance described in the analysis as 'mucilage,' but which is also known as *lichenin*. This substance is insoluble in cold water, but swells up and dissolves when boiled, and if present in sufficient amount sets to a yellowish jelly on cooling. Its chemical nature is obscure. When boiled with acids it yields a small quantity of sugar, but of what nature is not definitely determined.² Of this, however, there is no doubt, that the mucilaginous substance in Irish moss is quite unaffected by the ordinary starch-digesting fluids (saliva and pancreatic juice) met with in the body. For this reason its nutritive value must remain open to grave question, and at present one is only justified in regarding it as a substance capable of yielding a bland and soothing drink which may be of value in irritable conditions of the throat. It is sometimes recommended as a substitute for starch in cases of diabetes; but although it may not aggravate that disease, it is very doubtful whether it contributes in any important degree to the nourishment of the patient. That this is extremely unlikely is rendered still more evident by the fact that Irish moss jelly contains only 3 per cent. of solid matter, the remainder being water. A teacupful of such jelly would furnish only $\frac{1}{2}$ ounce of solid matter, or as much as the weight of a shilling. Whether the nitrogenous

¹ In a specimen of Irish moss which I examined, I found only 6.3 per cent. of nitrogenous matter and 16.6 per cent. of ash.

² The sugar does not appear to be glucose. I have not found that it ferments with yeast. It gives an imperfect pentose reaction with phloroglucin. The lichenin of Ireland moss gives on hydrolysis a large yield of a reducing sugar, which ferments with yeast, and gives no phloroglucin reaction (see also p. 269).

matter of Irish moss contributes to the nourishment of the body must also be left undetermined. It is not likely that it is all present in a protein form. The mineral constituents are very abundant, and contain traces of iodine, but not sufficient to exert any effects on nutrition.

Lichens.

The only lichen which we need consider is the so-called **Iceland moss** (*Cetraria islandica*). In its commercial form it resembles Irish moss, but is much darker in colour. According to Church's analysis, its composition is as follows:

Water	..	..	..	..	10.0	per cent.
Protein	..	..	..	..	8.7	"
Lichen starch	..	..	..	..	70.0	"
" acids, etc.	..	..	..	..	6.3	"
Cellulose	..	..	..	..	3.5	"
Mineral matter	..	..	..	..	1.5	"

A more recent analysis of the commercial article dried at 105° C. has been made by Ernest W. Brown,¹ with the following result:

Total nitrogen	..	..	..	..	..	0.56	per cent.
Protein nitrogen	..	..	..	..	..	0.32	"
Extractive nitrogen	..	..	..	..	..	0.14	"
Ether extract	..	..	..	..	..	1.2	"
Cellulose	..	..	..	..	..	5.3	"
Ash	..	..	..	..	..	2.2	"
Soluble carbohydrates (as dextrose)	..	..	..	..	..	43.3	"
Material soluble in 85 per cent. alcohol	..	..	..	..	..	16.1	"

He describes two kinds of carbohydrates as occurring in the substance: (1) Lichenin, which forms the jelly and yields dextrose on hydrolysis, but is unaffected by digestion and probably does not form glycogen; and (2) iso-lichenin, which is present in much smaller amount and resembles soluble starch, but on digestion yields only dextrins—no sugar.

It is evident from the chemical nature of the substance, from the resistance of its constituents to digestion, and from the small amount of it ever present in a jelly, that its nutritive value must be regarded as practically nil.

¹ *American Journal of Physiology*, 1898, i. 455.

CHAPTER XV

SUGAR, SPICES, AND CONDIMENTS

Sugar.

THE importance of sugar as an article of diet is so great that it may be well to devote a little space to its special consideration.

Several different varieties of sugar enter into the composition of articles of diet, but for practical purposes they may be divided into two groups: (1) The **sucroses**, known chemically as the disaccharids ($C_{12}H_{22}O_{11}$), the chief examples of which are cane-sugar (sucrose), beet-sugar, maple-sugar, malt-sugar (maltose), and milk-sugar (lactose); (2) the **glucoses**, or monosaccharids ($C_6H_{12}O_6$), exemplified by grape-sugar (dextrose), fruit-sugar (lævulose), and invert sugar, which is a mixture of those two, and is best known in the form of honey.

We may now consider each of these varieties in some detail.

1. **Cane-sugar**, or sucrose, is the most familiar of all kinds of sugar. It is most commonly derived from certain special grasses, such as the sugar-cane or sorghum, but occurs also in smaller amount in a great many plants and fruits. When derived from other sources than the sugar-cane, special names, such as beet-sugar or maple-sugar, are usually given to it; but it must be distinctly understood that these are chemically indistinguishable from the form of sugar derived from the sugar-cane.

Cane-sugar has been in use in the world as a food for many ages, but it is only within comparatively recent times that it has been manufactured cheaply enough to take an important place in ordinary diets. The following brief history of its introduction into Europe is taken from a valuable pamphlet on 'Sugar as Food,' issued by the United States Department of Agriculture:¹

'Sugar from the sugar-cane was probably known in China 2,000

¹ Farmers' Bulletin, No. 535, 1913.

years before it was used in Europe. When merchants began to trade in the Indies it was brought westward with spices and perfumes and other rare and costly merchandise, and it was used for a long time exclusively in the preparation of medicines. An old saying to express the loss of something very essential was, "Like an apothecary without sugar." Greek physicians several centuries before the Christian era speak of sugar under the name of "Indian salt." It was called "honey made from reeds," and said to be "like gum, white and brittle." But not until the Middle Ages did Europeans have any clear idea of its origin. It was confounded with manna, or was thought to exude from the stem of a plant, where it dried into a kind of gum. When in the fourteenth or fifteenth century the sugar-cane from India was cultivated in Northern Africa, the use of sugar greatly increased, and as its culture was extended to the newly-discovered Canary Islands, and later to the West Indies and Brazil, it became a common article of food among the well-to-do. In 1598 Hentzer, a German traveller, thus describes Queen Elizabeth, then sixty-five years of age: "Her nose is a little hooked, her lips narrow, and her teeth black, a defect the English seem subject to from their great use of sugar." By many the new food was still regarded with suspicion. It was said to be very heating, to be bad for the lungs, and even to cause apoplexy. Honey was thought to be more wholesome, because more natural than the "products of forced invention."

One of the earliest records of the use of sugar in this country¹ is to be found in the accounts of the Chamberlain of Scotland in the year 1319. Its price at that time was 1s. 9½d. per pound. Since then the consumption of sugar has increased so enormously that each of us in this country now uses between 80 and 90 pounds of it annually.²

The composition of the sugar-cane and its juice is about as follows:³

	<i>Entire Cane.</i>				<i>Juice.</i>
Water.. ..	71	04			79.4
Sugar	18	02			{ 19.6 (crystallizable), 0.3 (uncrystallizable).
Cellulose	9	56			
Albuminous matter.. ..	0	55			0.37
Fatty and colouring matter	0	35			
Soluble salts.. ..	0	12			{ 0.25
Insoluble salts	0	16			
Silica	0	20			

¹ See Bannister's *Cantor Lectures*, 1890.

² Calculated from the total sugar consumption of the United Kingdom. Some of this, however, is re-exported in a manufactured form as biscuits, jam, sweets, etc., so that it is probably nearer the mark to say that the average amount of sugar consumed daily by each individual in this country is 3 ounces.

³ Thorpe's 'Dictionary of Chemistry,' 1893, iii. 615.

In order to separate the sugar, the canes are crushed, and the expressed juice is then bleached by means of sulphurous acid, neutralized with lime, and all albuminous matters coagulated by boiling. It is then filtered, evaporated down, and the uncrystallizable sugar (glucose) separated by aid of a centrifuge. In this way the raw sugar is obtained in a crystalline form still mixed with impurities, while the residue is sold as molasses or treacle, or is used to make rum. The chief examples of raw cane-sugar are 'Barbadoes,' 'Clayed,' and 'Demerara,' the differences in these depending on the mode of manufacture. 'Barbadoes' is a very dark sugar, while 'Demerara' is characterized by a golden colour and well-defined crystal; it has also a fine flavour, due to its being prepared by the careful treatment of specially selected canes.¹

Raw sugar is purified by the process of refining, which consists in remelting the sugar, filtering it, and clarifying it by means of charcoal. It is then carefully evaporated *in vacuo*. If loaf-sugar is wanted it is run into moulds. Moulded cube-sugar is made in the form of sticks, and afterwards cut into cubes by machinery. Granulated sugars are made in the centrifuge. Other varieties depend on the mode of crystallization and grinding.

2. Beet-sugar.—Fully two-thirds of the 'cane'-sugar commonly used is really derived from the sugar beet. The following account of the growth of the industry is from the pamphlet already mentioned:

'Marggraf, a chemist, of Berlin, first discovered in 1747 that beets, with other fleshy roots, contained crystallizable sugar identical with that of the sugar-cane. In 1796 Marggraf's pupil, Achard, erected the first manufactory for beet-sugar, and in 1799 he brought the subject before the French Academy. He manufactured beet-sugar on his farm in Silesia, and presented loaves of refined beet-sugar to Frederick William III. of Prussia in 1797; but the 2 to 3 per cent. of sugar that could be extracted by the methods then in use was too small for commercial success. A new stimulus was given by the sugar bounties of Napoleon in 1806, and methods were rapidly improved, especially in France. Two great difficulties were still to be met: the percentage of sugar present in the beet was small (6 per cent.), and it was separated with great difficulty from the many non-sugar constituents, some of them acrid and of very unpleasant taste. Science now came to the rescue, and a beet was gradually developed having a larger percentage of sugar and a smaller percentage of the undesirable impurities. Barber says that

¹ Brown sugars contain more water than white, and a higher proportion of invert sugar. It is for these reasons that they are inferior in sweetening power to white sugar (see a paper by Marion C. Soar, B.Sc., 'Brown and White Sugars for Plain Cooking,' *Lancet*, January 29, 1921).

in 1836 18 tons of beetroot were necessary to produce 1 ton of sugar; in 1850 this quantity was reduced to 13·8, in 1860 to 12·7, tons; and in 1889 to 9·25 tons. From 6 per cent. of sugar, as found by Marggraf the sugar beet of good quality now contains 15 per cent. and more, 12 per cent. being considered necessary for profitable manufacture.¹

The sugar is extracted from the beets by rasping them to a pulp, extracting and evaporating *in vacuo*, with subsequent decoloration by means of animal charcoal.

To the ordinary consumer beet-sugar is hardly distinguishable from that derived from the sugar-cane, and it has already been stated that to the chemist the two are really identical.¹ There is no evidence for the statement sometimes made, that beet-sugar is more injurious to health than genuine cane-sugar; but I am informed by manufacturers that for some purposes sugar derived from the cane is preferable, *e.g.*, in the manufacture of fruit syrups and British wines. It is said to be less liable to fermentation.²

3. **Maple-sugar** is derived from the sugar maple of North America by tapping the bark in early spring and allowing the sap to escape as it flows upward. The sap is evaporated and the sugar allowed to crystallize out while the residue is used as maple syrup. One maple-tree yields about 4 pounds of sugar in a season.

There is no chemical difference between maple-sugar and that derived from the cane or beet, but it contains certain ethereal substances and organic acids which give it its peculiar flavour. It is probably on the presence of these that the slightly laxative qualities of maple-sugar depend. As a commercial source of sugar the maple cannot compare with either the cane or the beet, and maple-sugar is now chiefly used as a luxury and for the sake of its agreeable taste.

The average composition of these sugars in their raw state is as follows:³

Source.		Water.	Cane-sugar.	Other Organic Substances.	Ash
Sugar-cane ..	..	2·16	93·33	4·24	1·27
Sugar beet ..	..	2·90	92·00	2·59	2·56
Maple ..	..	—	82·80		

After being subjected to the process of refining, sugar is practically a pure chemical substance. It is indeed 'the purest food-substance in commerce' (Wynter Blyth).

¹ It has been aptly remarked by a writer in the *British Medical Journal* (1901, i. 1119), that the difference between cane-sugar and beet-sugar is 'not a chemical but a physiological one—a question of taste and flavour. It is a difference similar to that between *vin ordinaire* and Château Margaux, and between silent spirit faintly coloured and genuine Scotch whisky.'

² This is only true if the beet-sugar has been imperfectly purified.

³ 'Sugar as Food,' p. 12.

4. The remaining sugars of this group are malt-sugar, or **maltose**, and milk-sugar, or **lactose**. Both of these, though disaccharids, differ very considerably in chemical and physical properties from the sugars we have been considering. Milk-sugar has already been described (p. 110), and we may defer the study of maltose until we come to malt-extracts (p. 560).

Certain substances derived from cane-sugar deserve brief mention. When strongly heated, sugar melts into a yellowish liquid, and undergoes some physical alteration, so that on cooling it does not crystallize, but forms a transparent, brittle mass, familiar to everyone as **barley sugar**. If heated to a still higher temperature its colour darkens, and it acquires a bitter taste, the product being **caramel**, which is so largely used in cooking operations.

Treacle, **molasses**, and **golden syrup** are produced as by-products in the manufacture of crystallized sugar. Their syrupy consistence is in part due to the fact that the impurities which they contain prevent the cane-sugar from crystallizing, and partly also to their being fairly rich in uncrystallizable fruit-sugar. The following represents their composition :

					<i>West Indian Molasses.</i>	<i>Treacle.</i>	<i>Golden Syrup.</i>
Cane-sugar ..	..	..	..	..	47'0	32'5	39'0
Fruit-sugar ..	..	..	..	..	20'4	37'2	33'0
Extractive and colouring matter..					2'7	3'5	2'8
Salts ..	..	..	..	..	2'6	3'4	2'5
Water ..	..	..	..	..	27'3	23'4	22'7

It is interesting to compare the proportion of nutritive matter in these with that in malt-extract (p. 560), but to this subject we shall return later.

5. The other great group of sugars is the **glucoses**, or monosaccharids. The best example of these is **dextrose**, which occurs so abundantly in the grape. When grapes are dried to form raisins, the dextrose separates out, and may be recognised in the raisins in the form of little yellowish-white granular masses. Commercial glucose is usually got by boiling starch with acids. It occurs in a syrupy form. When heated it turns brown, and is used in cookery as 'sugar colouring.' Mixed with egg-albumin, it is largely employed in the preparation of 'icing' and 'fondants' in confectionery and in the manufacture of bonbons.

Fruit-sugar, or **lævulose**, is found, as its name implies, in most fruits. It is characterized by being almost uncrystallizable. It is hardly ever met with in an isolated form in dietetics, but is sometimes administered to diabetic patients, by some of whom it is better borne than any other form of sugar.

Invert sugar is a mixture of dextrose and lævulose. It can be prepared from cane-sugar by the action of ferments or by simple boiling, but more readily by boiling with acids. This 'inversion' of cane-sugar, as it is called, goes on pretty rapidly when cane-sugar is boiled with fruit-juice, the active agent being the vegetable acid of the fruit. Thus, a large proportion of the cane-sugar used in making jam is converted into invert sugar in the process. It is important to remember also that invert sugar does not crystallize.

Honey is the most familiar form of invert sugar. It contains about equal parts of dextrose and lævulose, its flavour being due to the presence of small amounts of volatile substances derived from the flowers. The mean composition of pure honey was found by Dr. Sieber to be as follows:

HONEY.

Moisture	19'98 per cent.
Grape-sugar (dextrose)	34'71 ..
Lævulose	39'24 ..
Substances other than sugar	5'02 ..

The comb consists of fatty substances, which are probably incapable of digestion.

The basis of **sweetmeats** is either cane-sugar or one of the glucoses. Sugar-candy is one of the purest. It consists of cane-sugar which has been allowed to crystallize round threads. It contains about 20 per cent. of water and 80 per cent. of crystallizable sugar.

Toffee consists of melted sugar and butter in almost equal proportions. Everton toffee has about 34 per cent. of cane and 27 per cent. of invert sugar, which has been derived from cane-sugar by the prolonged boiling. It is a highly nutritious substance, and makes an agreeable substitute for 'cod-liver-oil and malt' in the case of ill-nourished children.

Chocolate contains about 45 per cent. of cane-sugar, but no dextrose or lævulose. The rest of it is composed of cocoa-powder. (For analyses, see p. 328.)

Invert sugar, or a mixture of glucose and albumin, is largely used in the preparation of uncrystallized sweets, such as the creamy matter in the interior of chocolate drops.

The colouring of sweets is derived either from burnt sugar or from one of the anilin dyes, most commonly eosin. Cochineal is also a favourite colourer. It is interesting to note that aniline dyes may be excreted in the urine almost unchanged, and cases are on record where patients have been supposed to be passing blood, when they had merely been sucking red sweets. There is no reason to suppose, however, that such substances are in any way harmful to life.

Jams consist essentially of fruit preserved in a strong solution of sugar. We have already seen that the acids of the fruit, aided by the high temperature employed in the course of preparation, bring about the conversion of a considerable proportion of the cane-sugar into the invert form. Home-made jam is boiled for a longer time than the commercial article, and consequently contains more invert and less cane-sugar than the latter. Aitchison Robertson¹ gives the proportion of cane-sugar in most home-made jams as 20 per cent., while commercial jams have anything from 10 to 50 per cent. In some home-made jams which he examined the proportion of cane-sugar which had been inverted was as follows :

	<i>Proportion of Cane-sugar inverted.</i>			
Strawberry	two-fifths
Raspberry	three-fifths
Blackberry	four-fifths
Marmalade	five-sixths
Plum	six-sevenths

The importance of these figures is derived from the fact that the larger the proportion of cane-sugar which has been inverted, the less likely is the jam to interfere with digestion (see p. 278).

Commercial glucose, on account of its incapability of crystallizing, is often used to make jam from inferior fruit or from the remains of fruit, the juice of which has been used to make fruit syrups and jellies. Such jam may have a good appearance, but is deficient in fruit flavour. It is, however, quite wholesome and nutritious.

The gelatinizing power of jellies is due to the presence of pectin in the fruit (p. 255). If boiled too long, the power of gelatinizing is lost, and a syrup-results instead of a jelly. In commercial jellies gelatin is sometimes added to prevent this.

Almost half the weight of any given quantity of jam is made up of sugar in some form or another. The nutritive value of jam has already been considered (p. 137).

¹ 'The Value of Saccharine Foods as Articles of Diet,' *Scottish Medical and Surgical Journal*, 1898, iii. 30.

DIGESTION OF SUGAR.

The first factor which determines the digestibility of a sugar is its chemical form. No matter in what form sugar is consumed in the food, it can only be assimilated as a monosaccharid (dextrose or lævulose). Hence, we find that provision is made in the alimentary canal for the conversion, by means of suitable ferments, of all forms of sucrose (disaccharids) into dextrose and lævulose; *i.e.*, they are inverted. It is evident, then, that from a dietetic point of view we may speak of the sucroses as undigested and the glucoses as pre-digested sugars. It now becomes clear why sweet fruits are such important dietetic sources of sugar. It is because they contain the latter in a form in which it is fit for direct absorption into the blood. For the same reason honey must be regarded as a very easily digested saccharine substance, and the importance of the inversion which cane-sugar undergoes in the manufacture of jams also becomes manifest. The superiority of home-made over commercial jams is also set in a clearer light by reference to these considerations.

The second factor which influences the digestibility of a sugar is *the degree of concentration of its solution*. In strong solution sugar is an irritant to the tissues. In contact with the skin, it is apt to set up superficial inflammation. This is familiar in the form of the eczema which is apt to appear in diabetics from the contact of the sugar-containing urine with the skin, and from the similar condition occurring on the arms of grocers and other persons who have frequently to handle sugar, and it is on account of its irritating properties that sugar cannot be used as a subcutaneous aliment, though otherwise well adapted to fulfil that function. All attempts to use it in that fashion have been frustrated by the pain which it sets up (see p. 571). The same is true of the stomach. Brandl, experimenting on dogs, found that a 5·7 per cent. solution of sugar produced reddening of the mucous membrane; if the concentration was increased to 10 per cent., the mucous membrane became dark red, while a 20 per cent. solution produced pain and great distress. This irritating effect on the mucous membrane is accompanied by the production of much mucus and the pouring out of a highly acid gastric juice. These irritating effects seem to be much more pronounced in the case of cane-sugar than in that of the glucoses. Aitchison Robertson¹ injected 250 c.c. of a 20 per cent. solution of cane-sugar into the stomach of a patient who was suffering from chronic gastric catarrh. Shortly afterwards the patient felt sick,

¹ 'Digestion of Sugars in Some Diseased Conditions of the Body,' *Edinburgh Medical Journal*, 1894, xl., pt. i. 496.

and vomited a very acid fluid which put his teeth on edge. He complained also of heart-burn and flatulence, and of severe pain in the region of the stomach. A solution of invert sugar of the same strength produced no discomfort. The experiment was repeated with similar results in other cases of dyspepsia. The invert sugar produced no unpleasant symptom, and disappeared rapidly from the stomach, while the cane-sugar caused much distress, and remained for a long time.

The greater digestibility of invert sugar is here brought out again in great clearness. Cane-sugar may easily interfere with the digestion of other foods, by reason of the great outpouring of mucus in the stomach which its presence induces. Schüle¹ found that 10 to 30 grammes (2 to 6 lumps) of cane-sugar, when taken with an ordinary test breakfast, produced no appreciable effect on its digestion; but when the quantity was increased to 120 grammes considerable delay of digestion ensued. Seeing, he says, that one can easily take 80 to 100 grammes of sugar at dessert in the form of ices and sweets, a retarding action on the digestion of a meal must not unfrequently be manifested. Experiments by Ogata on dogs confirm these results.²

It is evident from all this that, if we wish to avoid the risk of interfering with digestion by the use of sugar, care should be taken that the latter is not consumed in a concentrated form,³ but that the comparative dilution in which sugar occurs in natural foods, such as fruits and milk, is imitated. This is of special importance in the case of dyspeptics, and the superiority of glucose for such patients over ordinary cane-sugar cannot be too strongly insisted upon.

Another matter affecting the behaviour of different sugars in the stomach is their tendency to undergo fermentation. Three varieties of such fermentation may be distinguished: (1) *Alcoholic*, resulting in the production of alcohol and acetic acid; (2) *butyric*, with the formation of butyric acid; (3) *lactic*, the product being lactic acid. Now, it is interesting to note that different sugars vary in the readiness with which they tend to undergo these different forms of fermentation. Some interesting experiments upon this point have been carried out by Aitchison Robertson.⁴ He arranges the sugars

¹ *Zeit. f. Klin. Med.*, 1896, xxix. 49.

² 'Sugar as Food,' p. 22.

³ Miller and Others (*Amer. Journ. of Physiol.*, 1920, 53, 65) found that large amounts of cane-sugar in concentrated solution interfere with digestion by depressing secretion and delaying evacuation. In quantities of two-thirds of an ounce no effect was produced.

⁴ 'Rate of Fermentation of Sugars,' *Edinburgh Med. Journ.*, 1894, xxxix, pt. ii. 803.

in the following order, according to the rapidity with which they tend to undergo each variety of fermentation :

<i>Lactic.</i>	<i>Butyric.</i>	<i>Alcoholic.</i>
Lævulose (most fermentable).	Lævulose (most fermentable).	Maltose (most fermentable).
Lactose.	Maltose.	Invert sugar.
Dextrose.	Dextrose.	Cane-sugar.
Invert sugar.	Invert sugar.	Dextrose.
Cane-sugar.	Cane-sugar.	Lævulose.
Maltose.	Lactose.	Lactose.

The practical deductions which he draws from his observations are these :

1. In dyspepsia the absorption of carbohydrates is delayed, and therefore all sugars tend to ferment.
2. In dyspepsia with lactic acid formation, one should avoid dextrose, lævulose and invert sugar, and use cane-sugar, maltose and lactose in moderate amount.
3. In butyric fermentation lactose should be preferred.
4. In alcoholic and acetic fermentation one should forbid invert sugar and lævulose, and give lactose.

It will be observed that, of all sugars, lactose is least liable to fermentation. This is another point in favour of the value of a milk diet in stomach complaints.

The last point connected with the influence of sugar on the digestive organs is its supposed **injurious effects on the teeth**. The impression that sugar-eating is bad for the teeth is so widespread that one can hardly suppose it to be devoid of all real basis. It must be admitted, however, that the supposition is not supported by any very conclusive observations. If sugar does destroy the teeth, it probably does so indirectly by lingering in the crevices of the mouth, and leading to the production of acids which eat away the enamel.

ASSIMILATION OF SUGARS.

The fate of sugar after entering the blood is to be converted by the liver into glycogen. What becomes of it after that is still disputed, but everyone is agreed that glycogen is the form in which sugar is stored in the body, for a time, at least. Now, it has been found by physiological experiment that it is not all sugars which are capable of being converted into glycogen. It is only those which can be *directly* fermented by yeast—fermented, that is to say, without being first changed into invert sugar.¹ Of the sugars commonly

¹ See Cremer, *Zeit. f. Biologie*, 1892, xxix. 484, and 1895, xxxii. 49; also Fritz Voit, *Deut. Archiv. f. Klin. Med.*, 1897, lviii. 523, and Achard and Weil, *Archives de Méd. Expér.*, 1898, x. 816.

consumed, cane-sugar and lactose are not directly fermented by yeast, and, in order that they may be stored up as glycogen, provision has to be made for their previous inversion. This is met, as we have seen, by the production of certain inverting ferments in the intestine which act on these sugars. If, however, these ferments happen, in any particular case, to be of feeble activity while the absorptive power of the intestine is great, some of the sugar may reach the blood unchanged, and, being incapable of conversion into glycogen, straightway appears in the urine. Even in the case of the directly fermentable sugars, if a large quantity is absorbed in the course of a short time, the glycogen-forming power of the liver may be unable to keep pace with the demands made upon it, and some of the sugar will appear in the urine. There results from this what is termed *alimentary glycosuria*. By giving large quantities of different sugars on an empty stomach, and observing whether or not glycosuria results, one has been able to determine what may be called the *assimilation limit* of each—that is to say, the maximum quantity which can be consumed at one time without the overflow of any of the sugar into the urine taking place. These maximum amounts are about as follows :

For lactose ..	..	..	120 grammes.
For cane-sugar ..	..	..	150 to 200 grammes.
For lævulose ..	..	..	200 grammes.
For dextrose ..	..	..	200 to 250 grammes.

Lactose, therefore, is the least assimilable of all sugars, and if taken in excess is the most likely to result in the production of glycosuria.

It must further be borne in mind that the assimilation limit is not the same for all individuals. Some people are able to convert more sugar into glycogen than others. It has been stated that persons with a low assimilation limit are potential diabetics ; that is to say, they are more liable than others to become the victims of diabetes mellitus.

There is another chemical fact relating to the assimilation of sugars which is of some practical interest, and it is this : Experiments have shown that the only sugars capable of direct fermentation, and therefore of conversion into glycogen, are those which contain either three carbon atoms or a multiple of that number. Those which contain five, seven, or any other number of carbon atoms cannot be converted into glycogen, and accordingly, should they gain access to the blood, are at once excreted in the urine. Now, sugars with five carbon atoms (pentoses) occur with considerable frequency in certain fruits, and hence pentosuria, as it is termed, is a not infrequent result of the free consumption of such foods

Notwithstanding all this, it must be noted that, if sugar be taken along with other food, and distributed uniformly over the day, very large quantities can be consumed without the danger of exceeding the assimilation limit. Vaughan Harley was able to take a pound of cane-sugar daily—with injurious results as regards his digestion, it is true, but without producing glycosuria. As a general rule, one may assume that $\frac{1}{4}$ pound can be taken daily without any bad results at all, but the exact amount must of necessity depend to a large extent on the muscular activity of the subject.

NUTRITIVE VALUE AND ECONOMY OF SUGAR.¹

We have seen that refined sugar is to be regarded as a practically pure carbohydrate. That being so, its food value must be high, for every gramme of it will yield 4.1 Calories of energy.² An ordinary lump of loaf-sugar weighs 5 grammes, and yields therefore fully 20 Calories. Four such lumps contain as much carbohydrate as a medium-sized potato. It is evident from these considerations that even the amount of sugar ordinarily added to a cup of tea may contribute in no small degree to the supply of energy required by the body daily. A pound of butter will yield about twice as much energy as a similar weight of sugar, but at nearly four times the same cost, for sugar is one of the cheapest fuel foods—perhaps the cheapest—which we possess, a shilling spent on it yielding 11,000 Calories, or more, even, than can be obtained in the form of bread for a similar expenditure.

This great cheapness of sugar is a development of recent years, and can hardly be without far-reaching effects on the national health. It tends to make us consume more carbohydrate and less fat, for fat is always a dear form of food. Whether this is an advantage it would be difficult to say. It is true that sugar can replace fat as a fuel in the proportion of $2\frac{1}{4}$ parts of the former to 1 of the latter, but it does not follow on that account that sugar can perform all the functions in the body which are usually fulfilled by fat, provided that proportion be observed. We have already learnt (p. 22) that sugar is more rapidly burnt up in the body than fat, and is on that account a more efficient protein-sparer than the latter. This rapid oxidation

¹ For an interesting discussion on this subject see a paper by Dr. H. Wilmoughby Gardner ('The Dietetic Value of Sugar') in the *British Medical Journal*, 1901, i, 1010.

² It has been calculated that a single caramel or a penny's worth of 'candy' contains sufficient Calories to provide the extra energy required in walking a mile (see C. G. and F. G. Benedict, 'The Energy Content of Extra Foods,' *Boston, Med. and Surg. Journ.*, October 2, 1919, p. 415).

is favoured by the ease with which sugar is absorbed, and, interfering as it does with the complete destruction of proteins, probably explains the bad effects sometimes observed from the use of sugar in gout and gravel (p. 509). The relative advantages of fat and sugar as fat-formers is another unsettled point. The highly fattening properties of sugar are undoubted; it is probably not only itself capable of being transformed into fat, but spares the body fat and part of that in the diet from combustion; but whether the fat so formed is as useful as that which can be stored up from the fat in the diet is a question which physiology is not yet in a position to solve. The point is one of some practical importance in the feeding of convalescents, and in the selection of cod-liver-oil or malt as a fattening agent.

Of this, however, there can be little doubt, that the great cheapness of sugar must have a favourable influence on the health and growth of children, for it ensures to them an ample supply of the body fuel which they so much need, and which the dearth of fat is apt to make unattainable. It has the advantage, too, of being a form of fuel which few children are likely to refuse, and that is far from being true of fat.¹

It is as a muscle food, however, that sugar is of special importance. We have already learnt (p. 37) that the carbohydrates are probably the chief source of muscular energy, and the sugars, on account of the ease and rapidity of their absorption, are better calculated to fulfil this function than any other member of the carbohydrate group.

It is interesting to note that Brillat-Savarin pointed out long ago that 'the English give sugar to their blood horses in order to sustain them in the trials to which they are subjected.' To Swiss guides and Arctic explorers, too, the value of such a saccharine food as chocolate has long been familiar. It was not until the year 1893, however, that Mosso first put the value of sugar as a muscle food to the test of experiment. By means of the ergograph he was able to show that sugar has a notable effect in lessening muscular fatigue.

¹ On the other hand, Bunge has uttered a warning note regarding the dangers incidental to the great increase in the dietetic use of sugar in recent times ('Der Wachsende Zuckerconsum und seine Gefahren,' *Zeit. f. Biolog.*, 1901, xli., p. 155). He points out that sugar, if largely eaten, must diminish the amount of other vegetable foods in the diet, whence there may result a deficit in the supply of calcium, iron, fluorine, and other mineral ingredients to the blood. This may tend to produce anæmia and caries of the teeth. He is of opinion that it is always dangerous to replace natural foods by pure isolated chemical products. I think it is not unlikely, too, that the greater consumption of sugar in recent years may have something to do with the increasing commonness of diabetes which many believe to exist.

The subject was then taken up by Vaughan Harley, who found, working under Mosso's direction, that if he took $17\frac{1}{2}$ ounces of sugar a day his power of doing work was increased 61 to 76 per cent. He showed also that the administration of sugar delays the onset of fatigue, and that its effects are rapidly exerted, the maximum influence being reached in about two hours. Schumburg¹ was able to confirm these results as regards *extraordinary* muscular exertion. Similar experiments have recently been performed by Prautner and Stowasser,² who found that when sugar was added to their diet their power of doing work was increased, while fatigue and nitrogenous waste were lessened. They conclude that sugar is a specially valuable food for persons who have to perform a single muscular effort, and especially if they are obliged to do so in a state of exhaustion.

The results of these scientific experiments, which were carried out with due regard to all possible sources of fallacy, have led to an extensive practical trial of sugar as a food for persons engaged in muscular labour. Two examples may be mentioned. During the autumn manœuvres of the German army some years ago, a number of the men were given ten lumps of sugar daily, in addition to their ordinary rations. The trial extended over five weeks, and it was found that the soldiers who had been supplied with sugar marched better and suffered less from hunger, thirst, and fatigue than their fellows who were not so supplied. As a result of the experiments, the surgeon in charge recommended that the sugar ration for soldiers should be raised to 60 grammes per day (about 2 ounces).

The other example illustrating the practical value of sugar as a muscle food is to be found in the experience of certain rowing clubs in Holland. They found sugar to be a very valuable food in training. The rowers who used it always won, on account of their superior powers of endurance, and it seemed to counteract the bad effects of an exclusively meat diet, so that the men did not become 'stale.'

'One case, as given in detail, is very interesting. Two schoolboys, seventeen and nineteen years of age, with only two hours a day for practice, at the end of two months entered for the rowing races. No change had been made in their diet except that they ate as much sugar as they wished, sometimes as much as one-third of a pound at the time of their daily exercise. One of them, however,

¹ *Archiv. f. Anat. und Physiol.*, 1899, Sup. Bd., p. 289.

² *Centralb. f. Inn. Med.*, 1899, xx. 169.

did not make this addition to his diet until the third week, when he began to show all the signs of overtraining—loss of weight, and a heavy, dull feeling, with no desire for study. On the third day after beginning the use of sugar these symptoms disappeared. At the time of the race both youths were in fine condition, and were victorious over their antagonists, who did not believe in the use of sugar. No bad after-effects were observed.¹

Additional evidence in favour of the free use of sugar in training and during the performance of hard muscular work has been brought forward by Steinitzer.² He has found from personal experience in Alpine climbing that his capacity for exertion is much greater when he partakes largely of sugar, whilst at the same time fatigue is lessened. The sugar is best taken in solution in quantities of from 5 to 10 ounces spread over the day. It may be dissolved in tea, wine and water, or lemonade. As much even as 20 ounces may safely be taken for several days on end during hard exercise without the least harm.

It certainly seems as if it would be worth the while of captains of football teams to try the effect of serving round small cups of black coffee, strongly sweetened with sugar, at 'half-time,' instead of the usual lemon. They would probably be rewarded by the greater endurance of their men in the second half of the match.)

Spices and Condiments.

The spices, condiments, and flavouring agents generally, are not, as a rule, *foods* in the strict sense of the term; that is to say, they are not capable of supplying the body with building material or energy. None the less, however, they are essential constituents of the diet. Their importance rests upon the power which they possess of improving appetite, and, by so doing, of increasing the digestive power. To the healthy man of vigorous appetite their presence is less essential. It has been found by experiment that meat from which all the flavouring ingredients have been extracted by prolonged boiling is as well digested by healthy men as fresh meat itself,³ in spite of the fact that it was eaten with but little relish.

To persons of jaded appetite, however, and to invalids and convalescents, the flavouring agents of the food are very powerful aids

¹ 'Sugar as Food,' p. 18.

² 'Die Bedeutung des Zuckers als Kraftstoff,' etc. (Berlin, Paul Parey, 1902).

³ Pettenkofer and Ziemssen's 'Handbuch,' Part I., p. 94, 1882.

to digestion, and no adjustment of the diet in such cases can be regarded as satisfactory which leaves this consideration out of account. Their presence justifies the inclusion in the regimen of many substances which are otherwise of little nutritive value, such, for example, as beef-tea.

The experiments of Pawlow¹ have placed the mode of action of these substances in a clearer light, and tend to enhance our sense of their importance. They appear to act partly through the organs of taste, in part reflexly, and in part also by a direct local action on the stomach. In all of these ways the appetite is aroused and the secretion of gastric juice promoted.² The direct irritant effect which some of them have upon the stomach contra-indicates their use in certain forms of dyspepsia in which the mucous membrane is in a state of congestion or slight catarrh. Many of them, too, exert a similar influence upon the organs of excretion, and for that reason they should be avoided by patients who are suffering from congestion of the kidneys or nephritis, or, indeed, inflammation in any part of the genito-urinary tract.

We have not space to study in detail the chemistry and composition of the vast number of flavouring agents which enter into the diet. It will be sufficient for us to glance for a moment at some of those in commonest use.

Mustard is derived from the seeds of the black or white mustard-plant (*Brassica nigra* and *alba*). The seeds of the white plant are the larger. They contain an acrid principle, but no essential oil. The black seeds contain a substance called myronate of potash, along with a ferment (myrosin), and these, when moistened with water, interact, producing the pungent essential oil to which the characteristic sharpness of mustard is due. The horse-radish (*Cochlearia armoracia*) contains an oil similar to that of black mustard.

Mustard flour contains from 15 to 25 per cent. of fixed oil, 0.5 to 2 per cent. of volatile oil, 35 to 45 per cent. of nitrogenous matter, 2 to 5 per cent. of cellulose, and 4 to 6 per cent. of mineral matter, along with a little starch (Snyder).

Black pepper is derived from the unripe berries of the *Piper nigrum*; white pepper is produced from the ripe fruit. The seeds contain an

¹ 'Die Arbeit der Verdauungsdrüsen,' Wiesbaden, 1898, chapter viii.

² More recent experiments on men have shown that the effect of spices on the secretion of gastric juice is very variable and inconstant, and probably depends to some extent on factors which vary in different individuals. On the other hand, their power of stimulating the movements of the stomach is invariable (see v. Korczynski, 'Ueber den Einfluss der Gewürze auf die Sekretorische und motorische Tätigkeit des Magens,' *Wiener Klin. Woch.*, 1902, xv. 468).

essential oil and an alkaloid (piperine), both of which contribute to the pungent taste of the substance. Cayenne pepper is derived from the pods of capsicum ; the small pods constitute chillies.

The basis of **vinegar** is acetic acid. Every 100 c.c. of good **vinegar** should contain 5 grammes of the acid, calculated in the glacial form. In genuine vinegars the acetic acid is produced by the oxidation of alcohol by a fungus (the *Mycoderma aceti*), while in **wood vinegar** it is produced by the destructive distillation of wood, the product being often coloured by the addition of burnt sugar. The source of the alcohol in genuine vinegars varies. In the best varieties weak wines are the source, and such vinegars retain a certain amount of 'bouquet,' derived from the wine. Solutions of alcohol derived from the fermentation of malt—dilute beers, in fact—are, or ought to be, the source of **malt vinegar** ; but this term is often used by manufacturers in a very misleading fashion, for in recent years dilute spirit derived from sugar or molasses has come much into use as a substitute for malt. It can scarcely be maintained that such a substitution is in any way injurious to health. Vinegar is often distilled, in order to make it keep better. The distillate contains the acetic acid, along with traces of alcohol and ether. This variety is said to be very popular in Scotland (Allen).

In addition to being a condiment, vinegar has an important action in softening the fibres of hard meat and the cellulose of green vegetables. Hence its use with such articles as crab and its addition to salads. Although the acetic acid which vinegar contains is ultimately oxidized in the body, with the production of alkaline compounds, there is still reason to believe that it has an unfavourable influence in gout, and may even precipitate an attack if freely indulged in.

Ginger is the root of a plant (*Zingiber officinale*) met with chiefly in India. It contains from 1·5 to 3 per cent. of volatile oil, and about 3 per cent. of fixed oil, along with a large amount of starch.

Cinnamon and **Cassia** are derived from the bark of several species of tropical plants. They contain volatile and fixed oils.

Cloves are the dried flower-buds of a tropical evergreen. They contain as much as 10 per cent. of volatile oil and a good deal of tannin.

Allspice, or **pimento**, is the fruit of a West Indian evergreen, which contains about 2·5 per cent. of volatile oil.

Nutmeg is the kernel of a small pear-like fruit which grows in the East Indies. **Mace** is the red fleshy mantle which envelops the seed.

These contain about 25 per cent. of fixed and 2·5 to 5 per cent. of volatile oils.

It only remains to add that sugar itself, in addition to its value as a food, is one of the most important of the condiments in common use, and, like all of these, is able to stimulate appetite and digestion if used in moderation. This justifies the consumption of sweets at dessert. Chemical substitutes for sugar which possess its flavouring qualities without its food value are **saccharin** (benzoic sulphamide) and **dulcin** (sucrol). The preparation known as **saxin** owes its sweetness to saccharin. **Porcherine** is another powerful artificial sweetener. These have many hundred times the sweetening power of sugar, but are of no use as foods. They are used to replace sugar as a flavourer, chiefly by diabetic, gouty, and obese patients.

CHAPTER XVI

MINERAL CONSTITUENTS OF THE FOOD

THE human body contains about 7 pounds of mineral matter, of which about five-sixths is in the bones. An analysis of the whole body would yield about 5 per cent. of ash. It is obvious from this that the mineral ingredients of the diet are important building material for the body, and are therefore to be regarded as foods in the strictly scientific sense of the term.

The chief mineral substances required in the food are sodium, potassium, calcium, magnesium, and iron, along with phosphorus, chlorine, sulphur, and traces of silica, fluorine, and iodine.

So necessary are these for maintaining intact the fabric of the body that death ensues within about a month if the supply of them is entirely cut off, even although all the other constituents of a normal diet are supplied as before.

Recent estimates of the amount of some of the chief mineral ingredients of the diet required per day are as follows:

	Grammes.		Grammes.
Phosphoric acid ..	.. 3 to 4	Calcium oxide..	.. 1 to 1.5
Sulphuric " ..	.. 2, 3½	Magnesium oxide ..	.. 0.3, 0.5
Potassium oxide ..	.. 2, 3	Chlorine ..	.. 6, 8
Sodium " ..	.. 4, 6	Iron ..	.. 0.006, 0.012

It being granted, then, that the mineral constituents of the food are important as tissue-builders, the question may next be asked, Are they of any value as sources of heat or energy? As regards the former, the reply is in the negative. The mineral substances in the food enter the body in a form too highly oxidized to be capable of yielding any heat in the tissues.

As regards the question of **supplying energy**, the reply is more doubtful. It is true that the substances under consideration cannot yield energy by oxidation in the way that the proteins, fats and carbohydrates do, but there is reason to believe that they *are* able to act indirectly as sources of energy in virtue of the osmotic properties

which they possess. It is found,¹ for example, that ordinary soup, by reason of its salts, possesses an osmotic pressure of from 7 to 9 atmospheres. Now, the body fluids have an osmotic pressure of only 6 atmospheres, and thus half a pint of soup will raise the osmotic pressure in the body by fully half an atmosphere. In this way absorption and the diffusion of the body fluids is aided, and such an action is equivalent to the supply of a certain amount of energy to the body. Thus it is that the mineral constituents of the diet may claim to rank as 'foods' on two grounds: they are builders of tissue and they are sources of potential energy as well.

We have next to inquire, **What amount of mineral matter must be supplied to the body daily?** To this inquiry no definite reply is forthcoming. We cannot tell how much of these substances is required for healthy nutrition in as precise a manner as we can calculate the need for carbon or for nitrogen, mainly for this reason—that many of the waste mineral matters of the body are excreted by the intestine, and we have no means of telling what proportion of these has merely escaped absorption, and how much has been excreted from the blood after playing a part in metabolism. This, however, one *can* say, that the amount of mineral matter found in an ordinary mixed diet is sufficient—nay, much more than sufficient—for all the needs of the body, and that amount is about 20 grammes, exclusive of such arbitrary additions as salt.²

As regards the *form* in which the mineral constituents enter into an ordinary diet, it may be said that many, if not, indeed, most of them, are in a state of organic combination. Thus, we find calcium and phosphorus organically combined in milk, iron in yolk of egg and in meat, sulphur in all protein-containing foods, and so on. It would appear, although the reason for it is obscure, that such organic mineral compounds are of special value in nutrition. It cannot be maintained, however, that it is *only* in such forms that mineral matter can find access to the blood. Experiment has shown that even such a substance as carbonate of lime is absorbed to some extent, for its administration is followed by an increased excretion of calcium in the urine,³ and the success which attends the treatment of cases of chlorosis by purely inorganic preparations of iron compels us to believe that the metal is capable of being absorbed in that form.

¹ Koeppe, 'Die Bedeutung der Salze als Nahrungsmittel': 68ten Versamm. Deut. Naturforscher und Ärzte. Frankfurt, 1896, Teil ii., Hälfte ii., p. 80.

² Bunge is of opinion that lime and iron are the only mineral ingredients of the diet which are ever likely to be present in too small amount (*Zeit. f. Biolog.*, 1904, xlv. (N.F., 27), p. 532).

³ Strauss, *Zeit. f. Klin. Med.*, 1897, xxxi. 493.

Notwithstanding these facts, it was found by Lunin that mice fed on desiccated milk lived quite healthily, whereas other mice which were given pure casein plus all the salts of milk in an inorganic form died.¹ No explanation of such results can be given, but they show that the form in which the mineral constituents of the food are presented to us is by no means a matter of indifference.

We may now pass on to consider the amount and kind of the mineral constituents met with in different articles of diet. It would serve no useful purpose, however, to present the reader with analytical tables professing to exhibit the precise percentage of the various components of the ash of different foods, for the reason that these are subject to very great fluctuations in kind and amount. This is specially true of vegetable foods, on the mineral ingredients of which the mode of cultivation and nature of the soil have such a marked influence. It will be more useful to take up the principal mineral substances required by the body separately, and to point out in general terms what articles of diet are richest in them. Let us begin with calcium.

Calcium.—It has been calculated, from analyses of human milk, that an infant requires about $\frac{1}{3}$ gramme (5 grains) of lime daily. The adult, owing to cessation of the growth of the bones, requires relatively less. Deficiency of lime in the food of an infant leads to softening of the bones; but this, though an element in rickets, is not really the root of that disease, for nothing is more certain than that an infant may suffer from rickets even although there has been an actual excess of lime salts in its food.

In later life various pathological conditions have been ascribed to an excessive consumption of calcium in the food. Amongst these are calculus, atheroma² and other calcareous degenerations, and habitual constipation. It must be admitted, however, that there is but little real evidence for such views. It is exceedingly doubtful whether the intestine ever absorbs more of any mineral substance than the tissues require, and if there is a tendency to the accumulation of such substances in any particular situation, the fault must be ascribed to some local change in the tissues, rather than to any undue increase of absorption.

Of common articles of diet, the richest in calcium is milk. It

¹ See also Socin, *Zeit. f. Physiolog. Chem.*, 1891, xv, 93, and Osborne and Mendel, 'The Inorganic Elements in Nutrition,' *Journ. of Biol. Chem.*, 1918, 34, 131.

² Rumpf, *Berliner Klin. Wochens.*, 1897, xxxiv, 265. The author recommends atheromatous subjects to adopt a diet poor in calcium salts, such, for example, as bread, fish, meat, apples and potatoes. See also Hirschberg (*Berliner Klin. Wochens.*, No. 46, 1911), who advises that the intake of calcium should be reduced in cases of spondylitis and arthritis deformans.

contains $1\frac{1}{2}$ grammes of lime in every litre; or, put otherwise, there is more lime in a pint of milk than in a similar quantity of lime-water. Next to milk come eggs, then the cereals—and especially rice—and then some vegetables, such as radishes, asparagus and spinach. Hard waters also must be regarded as important dietetic sources of calcium.

Foods poor in lime are meat (but only if derived from a fully-grown animal—veal, for example, being comparatively rich in calcium¹), fish, bread, fruits and potatoes.

The importance of milk and eggs as foods for growing children will be apparent from these facts, while if one should for any reason desire to construct a dietary containing a minimum of lime, it would be well to draw its ingredients from the members of the second group.

Magnesium is usually present in foods in the same proportion as calcium. There are exceptions to this rule, however, for in milk magnesium is less, and in meat rather more, abundant than calcium, while in bread there is actually five times as much of the former as of the latter.²

Iron is one of the mineral constituents of the diet of which one may say that it is always present in an organic form. It is also mainly excreted in the fæces, and this fact has led to great difficulty in attempting to estimate the amount of it required by the body daily. Roughly speaking, there are about 10 milligrammes of the metal contained in an ordinary mixed diet (Stockman), and that quantity must therefore be regarded as sufficient to meet all physiological demands.³

It is difficult to give precise figures as to the amount of iron present in different articles of diet. In animal foods it depends very much on whether the animal was bled or not, while in vegetable foods it varies very greatly with the amount of iron in the soil. Bunge⁴ arranges some common foods in the order of their richness (not the richness of their ash) in iron as follows: Spinach, yolk of egg, beef, apples, lentils, strawberries, white beans, peas, potatoes, wheat.

¹ See Katz, *Pflüger's Archiv*, 1896, lxiii. 1.

² See Richet's 'Dictionary of Physiology.'

³ A study of several typical American diets (United States Department of Agriculture, Office of Experiment Stations, Bulletin 185, 1907) shows that the majority yield from 11 to 19 milligrammes of iron per day.

⁴ Bunge, 'Der Kalk und Eisengehalt unserer Nahrung,' *Zeit. f. Biolog.*, 1904 (N.F. 45), xxvii. 532.

Boussingault¹ gives the following proportions of iron in 100 parts of the following foods examined in the fresh condition :

PROPORTION OF IRON PER 100 PARTS OF FRESH SUBSTANCE.

Blood of ox	0.03750
" pig	0.06340
Beef	0.00480
Veal	0.00270
White fish	0.00150
Egg	0.00570
Wheaten bread	0.00480
Haricots	0.00740
Oats	0.01310
Lentils	0.00830
Potatoes	0.00160
Milk	0.00180
Carrots	0.00090
Maize	0.00360
Rice	0.00150
Apples	0.00200
Spinach	0.00450
Cabbage	0.00390
Burgundy	0.01090
Beer	0.00400

} in one litre.

Stockman has pointed out² that these results are too high, probably from faulty methods of analysis. He gives the following amounts of iron in some common foods :

1 pint of milk	2.2 milligrammes iron.
100 grammes of oatmeal	3.1 ..
300 " fine bread	1.8 ..
280 " common bread	1.1 ..
120 " beef-steak	4.7 ..

From the results available, it may be concluded that beef and yolk of egg³ are foods richest in iron, while milk and its derivatives, such as cheese, are amongst the poorest ; but even 5 pints of milk would supply the 10 milligrammes of metal required in the daily diet. Oatmeal and Egyptian lentils are amongst the richest in iron of vegetable foods, but bread, rice, potatoes and spinach also contain a good deal. As regards an ordinary mixed diet it may be said that the amount of iron which it contains is roughly proportional to its richness in protein, for these two constituents tend to run parallel to each other. It should be noted that the iron contained in hæmoglobin and its derivatives is very ill absorbed.⁴ It is all the more necessary

¹ *Comptes Rendus*, 1872, lxxiv. 1355.

² Stockman (R.), *Journ. of Physiolog.*, 1895, xviii. 484, and 1897, xxi. 55 ; also *Brit. Med. Journ.*, 1895, ii. 1473. For later analyses see 'Iron in Food' (United States Department of Agriculture, Office of Experiment Stations, Bulletin 185, 1907).

³ See Katz, *Archiv f. d. Gesam. Physiolog.*, 1896, lxiil. 1 ; also Hartung, *Zeit. f. Biolog.*, 1902, xliii. 195.

⁴ V. Starck, *Deut. Med. Wochensch.*, 1898, xxiv. 805.

to point this out, as hæmoglobin preparations are beginning to find a place in the treatment of anæmia.

Amongst beverages, some mineral waters—*e.g.*, Kronthal (green label)—contain a good deal of iron, and tea-leaves also are very rich in it, but probably little of the metal finds its way into the infusion. Wines are poor in iron, even the so-called ferruginous varieties having but a small proportion.

That the habitual consumption of foods poor in iron may lead to anæmia is possible, though it is difficult to imagine a diet that would not contain the small amount of the metal required daily. Verdeil and Subbotin, however, have certainly found that the ash of the blood of dogs fed on meat contained much more iron than that of animals nourished on bread; and V. Hoesslein has shown that if young animals receive only as much iron as adults they become anæmic.

On the other hand, once any marked deficiency of iron in the blood exists, it is almost impossible to make it good by merely dietetic means; for no food is rich enough in iron salts to be able to accomplish the object in view. Hence, a knowledge of the amount of iron contained in different foods is, after all, of but little therapeutic value.

Sodium and Potassium.—Sodium is required in the body for the proper constitution of its fluids; potassium for the construction of cells, and specially, perhaps, of the red blood cells and the muscles. Young animals deprived of potassium do not develop good muscles. As regards the amount of sodium and potassium contained in different foods, it may be said that the vegetable group is richest in the latter, and the animal group in the former.

Bunge gives the following table of proportions:

To 1 equivalent of sodium there is—

In yolk of egg				1 equivalent of potassium.
„ milk .. .. .	..	..	..	0·8 to 6 equivalents of potassium.
„ veal .. .. .	..	..	..	4 „ „
„ wheat .. .. .	..	..	..	12 „ 23 „ „
„ potatoes .. .. .	..	..	..	31 „ 42 „ „
„ peas .. .. .	..	..	..	44 „ 50 „ „

Sodium is chiefly taken in the form of sodium chloride, or common salt. Of this most people consume about 20 grammes daily, which is probably at least ten times as much as is really necessary to meet the needs of the body. There are not wanting

people who maintain that this excessive consumption of salt is not only needless, but even harmful, as tending to throw a strain upon the kidneys, which may end in injuring them permanently, and as perhaps contributing to the production of gout, diseases of the skin, and chronic catarrhs.¹

These views, however, are not yet proven. It may be admitted—for the experience of those who refuse to add any salt to their food amply proves it—that the amount of sodium chloride contained in a natural form in ordinary foods is quite sufficient for our needs; but there is no proof that an extra addition of salt in the form of a condiment is really injurious to health. On the other hand, it is equally far from being proved that such addition conduces in any way to the well-being of the body. It has been asserted, for instance, that the addition of salt to the food aids digestion (Ogata), but more recent and exact experiments have shown that—in health, at least, and in moderate doses—salt has very little real influence on digestion at all, while in large quantities it actually delays the process.² If, moreover, sodium chloride is entirely removed from the food, the secretion of hydrochloric acid is lessened, or even arrested altogether, and upon this basis it has been urged that one should limit the use of salt in cases of hyperacidity of the stomach. Where, on the other hand, appetite is poor and digestive power feeble, the moderate use of salt in the food may act as a digestive stimulant in the same way as any other condiment. There is also reason to believe that it may slightly aid the absorption of food.³

On the general processes of nutrition in the body, salt seems to be equally devoid of any pronounced effects. On the one hand it has been maintained that it acts as a cell stimulant,⁴ while on the other it has been denied, on seemingly equally good grounds, that it has any distinct influence on metabolism at all. The latest and most conclusive experiments⁵ tend to show that any action salt may have is in the direction of lessening nitrogenous waste, *provided a sufficiency of water is supplied at the same time.*

The craving for salt as an addition to the diet seems to be specially

¹ See a paper by R. Ackerley, 'Saline Waters, and the Use and Abuse of Common Salt,' Proc. Roy. Soc. of Med., February, 1910.

² See Pawlow, 'Die Arbeit der Verdauungsdrüsen,' and Schüle, *Zeit. f. Klin. Med.*, 1895, xxviii. 492, and 1896, xxix. 49.

³ Gabriel, *Zeit. f. Biolog.*, 1892, xxix. 554.

⁴ Garnier and Lambert, *Archives de Physiolog.*, 1898, xxx. 421.

⁵ Walther Straub, *Zeit. f. Biolog.*, 1898, xxxvii. 527. For a recent review of the whole subject, see Belli, *Zeit. f. Biolog.*, 1904 (N.F. 27), xlv. 182.

strong amongst vegetable-feeders. An ingenious explanation of this fact has been advanced by Bunge on the lines that the large proportion of potassium in vegetable substances would tend to drive all sodium out of the body were the latter not constantly reinforced by the addition of salt to the food. This theory has been strongly criticised by Forster and others, and it is doubtful if it can be regarded as tenable—at least, in the extreme form in which it was brought forward by its distinguished author. Whatever the explanation, however, the fact remains that the artificial addition of salt is apparently more necessary in the case of people who live mainly on vegetable products than in those who consume a mixed diet.

Phosphorus.—The importance of phosphorus as a building material in the body can scarcely be overrated.¹ Wherever growth is most active there most phosphorus is found. It enters into the composition of all cell nuclei, and it is abundantly present in the bones and in the central nervous system. One would naturally expect, therefore, that wherever the building up of such tissues is going on rapidly a large supply of phosphorus will be required in the food, and it is not surprising to find that the development of young animals which are deprived of it is apt to be seriously impaired. Hence the great importance of a due supply of phosphorus in the food of growing children.

The percentage of phosphoric acid (P_2O_5) in some fresh foods is as follows: ²

<i>Vegetable.</i>				<i>Animal.</i>			
Carrot	..	..	0·036 per cent.	Pork	..	..	0·160 per cent.
Turnip	..	..	0·058	Milk	..	..	0·220
Cabbage	..	..	0·089	Beef	..	..	0·285
Potato	..	..	0·140	Eggs	..	..	0·337
Chestnuts	..	..	0·200	White cheese	..	..	0·374
Barleymeal	..	..	0·230	Mutton	..	..	0·425
Haricots	..	..	0·924	Gruyère cheese	..	..	1·350

The superiority of most animal foods in respect of this constituent is at once apparent.

The phosphorus contained in foods is, for the most part, present in an organic form of combination, sometimes of a very complex sort, but in part also in an inorganic form as phosphates of the alkalis or earths.

¹ Osborne and Mendel found that a deficiency of magnesium, potassium, sodium, or chlorine in the diet does not interfere with the growth of rats, whilst a deficiency of calcium or phosphorus does so very greatly (*Journ. of Biol. Chem.*, 1918, 34, 131).

² Girard, *Comptes Rendus*, 1896, cxxii, 1387.

There is reason to believe that the organic forms are the more valuable for contributing to the growth and repair of tissue.¹ Examples of these are the chemical substances nuclein, lecithin, glycono-phosphoric acid, phospho-carnic acid and phytin, all of which are probably valuable dietetic sources of the element. The foods richest in these are such articles as yolk of egg, thymus, fish-roe, calves' brains, and the germ of wheat. **Phytin** is particularly rich in organic phosphorus. It is an acid calcium magnesium salt of anhydrous oxymethylene diphosphoric acid contained in the seeds and tubera of plants. Being readily assimilated it is a valuable means of enriching the diet in phosphorus.

It is doubtful, on the other hand, whether the inorganic compounds containing phosphorus are of much value in the body. They seem to be almost immediately excreted by the kidney or bowel, probably without exercising any important influence on metabolism.

Cerebos salt consists of a mixture of 4 parts of calcium and magnesium phosphates with 96 parts of common salt. The phosphates in such a preparation are present in a purely inorganic form, and are therefore of doubtful utility. In any case the recommendation of such preparations is based upon the groundless assumption that an ordinary mixed diet is too poor in phosphorus to be able adequately to supply our need of that substance. It has been calculated that less than 2 grammes of phosphates are required to meet the daily needs of the body and that an average mixed diet contains from 3 to 5 grammes or more (Snyder). It may be remarked in this connection that we know of no diseased condition which can be clearly traced to a deficiency of phosphorus in the diet. This is true, indeed, not of phosphorus alone, but of all the other mineral ingredients of the diet with the exception of iron, and possibly also of calcium. A deficiency of iron in the food may, as already remarked, lead to the development of anæmia, and too little lime

¹ Keller, however, in a review of the whole question (*Zeit. f. Diät. und Physik. Therapie*, 1901, iv. 669), concludes that although phosphorus in organic combination is fully absorbed and assimilated, yet it has not been conclusively proved that it is more useful in this form than the inorganic phosphates, and still less that organic combinations of phosphorus are essential for life and growth. Hart, McCollum, and Fuller, also, found in experiments on pigs (*Amer. Journ. of Physiol.*, 1908-09, xxiii. 246) that the administration of calcium phosphate could prevent the effects of a low phosphorus ration, and gave as good results in this respect as such an organic phosphorus compound as phytin. On the other hand, Tunnicliffe (*Archiv. internat. de Pharmacodynamie et de Thérapie*, 1906, xvi. 207) found that the addition of calcium phosphate to the food of children did not increase the amount of phosphorus assimilated or retained, whereas the addition of an organic phosphorus compound did.

in the food may cause the bones of children to become soft; but with these rather doubtful exceptions it may be safely assumed that any ordinary diet will amply provide for all the mineral matter we require. If one should for any reason think it advisable to increase the proportion of phosphorus in the food, it would be wiser to have recourse to those articles already mentioned in which it is present in an organic form, rather than to pour into the body inorganic compounds which will probably be excreted from it just as they entered. That such organic forms are well absorbed there is now no doubt.¹

Oxalic acid, though not strictly speaking a mineral substance, may be conveniently considered here, for it is usually present in the diet in the form of oxalate of lime. Esbach gave the following table of the amount of oxalic acid in different articles of food :²

					Per 1,000.
Black tea infused 5 minutes	..	..	..	..	2'060
Cocoa-powder	..	..	..	..	3'520 to 4'500
Pepper	..	..	..	..	3'250
Coffee ..	..	..	..	..	0'127
Parsley	..	..	..	..	0'006
Haricots	..	..	..	..	0'312
Common beans	..	..	..	..	0'158
Potatoes	..	..	..	..	0'046
Good bread	..	..	..	..	0'047
Crust ..	..	..	..	..	0'130
Crumb	..	..	..	..	0'120
Buckwheat flour	..	..	..	..	0'171
Barleymeal	..	..	..	..	0'039
Maize flour	..	..	..	..	0'033
Sorrel	..	..	..	..	2'740 to 3'630
Spinach	..	..	..	..	1'910 to 3'270
Rhubarb	..	..	..	..	2'466
Brussels sprouts	..	..	..	..	0'020
Cauliflower	..	..	..	..	0'003
Beetroot	..	..	..	..	0'390
French beans	..	..	..	..	0'060 to 0'212
Salsifies	..	..	..	..	0'070
Tomatoes	..	..	..	..	0'002 to 0'052
Carrots	..	..	..	..	0'027
Chicory	..	..	..	..	0'103
Dodder	..	..	..	..	0'045
Endive	..	..	..	..	0'017
Lettuce	..	..	..	..	0'016
Dried figs	..	..	..	..	0'270
Currants	..	..	..	..	0'130
Prunes	..	..	..	..	0'120
Gooseberries	..	..	..	..	0'070
Plums ..	..	..	..	..	0'070
Raspberries	..	..	..	..	0'062
Oranges	..	..	..	..	0'030
Lemons	..	..	..	..	0'030
Cherries	..	..	..	..	0'025
Strawberries	..	..	..	..	0'012

¹ See Bergell, *Fortschr. der Med.*, 1898, xvi. 1.

² For other estimations see a paper by Apollina, 'Ueber die Oxalsäure im Organismus,' *Berlin. Klin. Wochens.*, 1901, xxxviii. 544.

It will be observed from the table that oxalic acid occurs in relatively large amounts in tea, cocoa, spinach, rhubarb, sorrel, and pepper. Tomatoes are sometimes said to be rich in it, but this would appear to be an error. Their sour taste is due to the presence of citric acid. An animal diet diminishes the excretion of oxalic acid owing to the small amount of it which animal foods contain.¹

There would seem to be little doubt that the consumption of foods rich in oxalic acid may be a cause of the production of oxalic calculus. Dr. Prout, for example, states that he has seen well-marked instances in which an oxalate of lime nephritic attack has followed the free use of rhubarb (in the shape of tarts, etc.), particularly when the patient has been in the habit at the same time of drinking hard water. On the other hand, the condition of so-called oxaluria seems to have no relation to the amount of oxalates in the diet, but to be merely a variety of acid dyspepsia.

Sulphur is present in the food almost entirely in a state of organic combination—chiefly in proteins. The amount of it present in these varies considerably, as is shown by the following analyses of dry proteins.² There is in—

Dried egg-white	..	..	..	..	1·80 per cent.
„ syntonin	..	..	..	..	1·80 „
„ albumin of wheat	..	..	..	..	1·55 „
„ „ peas	..	..	..	..	0·40 „
„ gluten	..	..	..	..	0·70 „

We know nothing of the advantages or otherwise of an increase or diminution of sulphur in the food.

Chlorine is taken in almost entirely in the form of sodium chloride, or common salt. Except as a source of hydrochloric acid, nothing is known of its uses in the body, but the peculiar behaviour of the chlorides in some acute fevers would point to some special rôle attaching to them in metabolism.

Iodine is present in small quantities in fish.³ Thus, herring contain 2 milligrammes per kilo, mussels 1·9 milligrammes, salmon 1·4, ling and cod 1·2, and oysters 1·2. The only situation in the body in which this element has been detected is the thyroid gland, and the significance of its presence in the food is as yet quite obscure, though it may one day prove to be of some importance.

Fluorine and silica are present in the body in small quantities, chiefly in the teeth and bones. Vegetable foods, and especially the cereals, are their most abundant source in the diet.

¹ J. C. Dunlop, *Journal of Pathology and Bacteriology*, 1896, iii. 389.

² 'Richter's 'Dictionary of Physiology.'

³ See *Lancet*, 1899, ii. 1030 (abstract).

The question of the acidity or alkalinity of foods may be conveniently dealt with here. According to the reaction of their ash, foods may be divided into three groups:¹ (1) Acid foods, *i.e.*, those which leave on incineration an acid-reacting ash; (2) neutral food, with neutral ash; and (3) alkaline foods, the ash of which is alkaline in reaction.

Examples of these groups, arranged in the order of their acidity or alkalinity respectively, are as follows:

<i>Acid Foods.</i>	<i>Neutral.</i>	<i>Alkaline.</i>
Oats.	Sugar.	Carrot.
Barley.	Vegetable oils.	Turnip.
Beef.	Animal fats.	Potato.
Wheat.		Onion.
Eggs.		Milk.
Rice.		Blood.
Maize.		Peas.
		Lemon-juice.
		Orange-juice.
		Beans.

Wright is of opinion that the exclusion from the diet of a sufficient quantity of 'alkaline' foods leads to the development of scurvy and other diseases characterized by a diminution of blood coagulability. It is not improbable, also, that the proportion of acids or alkalies in foods may have important bearings on gout, but a discussion of the question would lead us into the sphere of too many controversial matters. At all events, it is probably safest to allow the 'alkaline foods' to predominate to some extent in the diet.

¹ Wright, 'On the Pathology and Therapeutics of Scurvy,' Army Medical Reports, 1895, xxxvii. 394. It must be pointed out that the reaction of the ash of foods still requires elucidation. I have not been able to find, for example, that meat leaves an acid-reacting ash, although this may be due to the blood contained in the meat. For a discussion of the question, see Sherman's 'Food Products' (Macmillan Co., 1914), p. 352.

CHAPTER XVII

WATER AND MINERAL WATERS

ABOUT two-thirds of the total weight of the body is made up of water. The importance of water as a tissue-builder and its right to rank as a true 'food' are at once apparent from this statement.

About $4\frac{1}{2}$ pints of water are given off from the body every day in the various excreta and exhalations, and of this about one-sixth is actually formed in the tissues out of hydrogen and oxygen, the remainder being derived from the food and fluids consumed. If one reckons that half of the whole weight of solid food taken consists of water, then the amount required to be added to the diet in an actually fluid form would be approximately $2\frac{1}{3}$ pints (about two breakfast-cupfuls and three tumblerfuls). Obviously, however, the exact amount must vary very greatly with external conditions, and especially with the amount of sweat produced.

The nature of the diet has also an important influence on the amount of water consumed. On this point some interesting observations have been made by Voit, examples of which are contained in the following table :

<i>Food consumed.</i>			<i>Water consumed.</i>	<i>Water in Fæces.</i>
800 grammes of bread ..	..	..	1,151 grammes.	212 grammes.
500 " of meat and	200 of fat..		760 "	25 "
500 " "	200 of starch		646 "	16 "
1,500 " of meat ..	..	..	1,238 "	10 "

It will be observed that, upon the whole, the amount of water consumed is proportionate to the amount contained in the fæces. Where, as in a bread diet, the fæces are rich in water, an increased amount of fluid is consumed in order to make up for the loss from the bowel. This fact is entirely opposed to the statement not infrequently made, that a diet mainly composed of vegetable ingredients tends to lessen thirst. On the other hand, if nitrogenous food, such as meat, is eaten in large quantities, the consumption of water must also be increased, owing to the necessity for providing for the proper elimination of urea and other products of nitrogenous waste.

For this reason the body tends to become richer in water if the diet is composed chiefly of fats and carbohydrates, and poorer in water if the food be rich in protein. We have already seen that this excess of water in the body is one of the consequences of a purely vegetable diet.

EFFECTS OF AN INCREASE OR DIMINUTION OF WATER IN THE DIET.

If a litre of water be swallowed on an empty stomach, almost the whole of it has been excreted in the urine within the space of three hours. This result is not due to mere dilution of the blood, for if normal salt solution be taken instead of water the result is precisely the same.¹ The real explanation would appear to be that the total volume of the circulating fluid in the body is a fairly fixed quantity, and is maintained by some regulating mechanism, so that it is not possible permanently to increase it. Nor can the volume of the blood be much reduced by diminishing the amount of water consumed. It is probable that such an effect can only be produced for a very short time. Experiments have shown² that if the water of the diet be reduced by about 27 per cent. there is indeed evidence that the blood becomes more concentrated, for in one such case the solids of the plasma rose from 8.8 to 11.6 per cent., the number of red corpuscles from 4,800,000 to 5,580,000 per cubic millimetre, and the specific gravity of the serum from 1027.4 to 1033.4. At the same time the arterial tension and the volume of the pulse were diminished. It was found, however, that equilibrium was very readily established, so that in a subsequent experiment the results were much less pronounced. This equilibrium seems to be brought about by an interchange of fluid between the blood and the tissues. If the blood becomes more concentrated, water passes into it out of the tissues to make good the deficiency, so that the latter become drier. Hence it is that if the tissues become water-logged, as they do in cardiac dropsy, good results may be obtained by restricting the amount of fluid in the diet, for the tissues will then drain themselves into the bloodvessels. Conversely, if the blood be habitually overloaded with water, as it is apt to be, for example, in those who habitually consume large quantities of beer, some of the surplus passes out of the vascular area into the tissues, which then become abnormally

¹ See Falck, *Archiv f. Physiol. Heilkunde*, 1852, xi. 125, and Schmaltz, *Deut. Archiv f. Klin. Med.*, 1891, xlvii. 145.

² Dennig, *Zeit. f. Diät. und Physik. Therapie*, 1898, i. 281 and ii. 292.

watery. The tissues are therefore, in a sense, reservoirs of water, and it is to the rapid emptying or filling of these that sudden alterations in the weight of the body are usually to be ascribed. For example, in the experiment just mentioned, in which the fluids of the diet were reduced 27 per cent., the patient lost 8 per cent. of his weight within a week. It is important to bear this influence of water on the body weight in mind, for there is no doubt that the fluctuations which it brings about are often erroneously attributed to the loss or storage of solids such as fat. Much of the loss of weight in acute fevers, for instance, is certainly due to increased dryness of the body, and its very rapid restoration during convalescence is the result of a retention of water in the tissues. The same holds good for obesity. Those who have insisted upon the aid which a restriction of the fluids of the diet furnishes in reducing a patient's weight have too often forgotten that the reduction is **not** necessarily due to the removal of fat. But we shall return to this subject in discussing the dietetic treatment of obesity.

It has been stated that we are unable, by increasing or diminishing the amount of water in the diet, to bring about any *permanent* alteration in the volume of the blood. It must not be concluded from this that any regulation of the fluid consumed is entirely without effect in cases of disease affecting the cardio-vascular apparatus. Quite the contrary is the case. The mere temporary rise in the volume of blood to be driven round the circulation which the consumption of a large quantity of fluid brings about, and the increased labour which its excretion entails, may of themselves seriously hamper an already embarrassed heart; and for this reason the amount of water in the diet, in cases of advanced cardiac disease and dropsy, may often be greatly reduced with nothing but benefit to the patient.¹ On the other hand, it must always be remembered that, if the consumption of fluid be reduced to the extent of increasing the viscosity of the blood, one increases thereby the resistance offered in the capillary circulation, and the increased strain thus thrown upon the heart may end by doing more harm than the restriction of the volume of the blood does good.

One may perhaps best avoid both dangers by seeing that the amount of fluid consumed is not only moderate in quantity, but is evenly distributed over the day, so that there is no period at which the total volume of the blood is unduly swelled.

It will be understood that very much the same remarks apply to

¹ A reduction to 30 ounces or less per day can usually be managed without any difficulty.

the treatment of aneurysm. What we have to avoid in that disease is throwing any undue strain upon the weakened vessel walls, and that can best be done by taking care that the circulation is never flooded by the sudden access of a large quantity of extraneous fluid. For a similar reason it is often advisable to restrict the consumption of fluids after severe hæmorrhage, in spite of the great thirst of which the patient usually complains, for the vascular strain which any increase in volume of the circulating fluid must inevitably bring about may be quite sufficient to start the bleeding afresh.

INFLUENCE OF WATER ON DIGESTION.

The first point which it is necessary to emphasize in this connection is that *water is not absorbed by the mucous membrane of the stomach*. This is certainly a surprising fact, but it has been incontestably established both by physiological experiment and by observations on patients suffering from obstruction at the outlet of the stomach.

When water enters the stomach, it begins to flow out into the intestine almost at once, the process going on in little gushes through the pylorus until all has escaped. Roughly speaking, one may assume that a pint of water will have entirely passed from the stomach in the space of about three-quarters of an hour.¹ The precise rate of leaving, however, is very markedly influenced by temperature. Hot water escapes from the stomach much more rapidly than cold.² The heat increases powerfully the movements of the stomach walls, and at the same time seems to cause the pylorus to open, so favouring the escape of the contents. The stimulating effects which hot water exerts on gastric peristalsis render it a powerful aid to sluggish digestion, while the 'unlocking' of the pylorus which it brings about is probably the explanation of the almost instantaneous relief which it affords in many cases of stomach pain.

The fact that water is exclusively absorbed in the intestine has important bearings on the treatment of patients suffering from dilated stomach. In the extreme form of that disease, when the stomach contents are quite unable to escape through the pylorus, the entrance of water into the blood is arrested, and the patient is the victim of a 'tissue thirst,' to which much of the emaciation and discomfort from which he suffers must be attributed. Not only is this so. The deficiency in the supply of water to the blood may go

¹ Moritz, *Münch. Med. Wochensch.*, 1894, xli. 816.

² Schüle, *Zeit. f. Klin. Med.*, 1895, xxviii. 462 and 1896, xxix. 49.

so far that the proper excretion of waste products is interfered with, and toxic symptoms, such as coma or convulsions, may then supervene. In such cases there is an imperious necessity for getting water into the blood by some route other than the stomach, preferably *per rectum*.

The rapidity with which water passes through the stomach causes it to be a very dangerous vehicle of infection, for the hydrochloric acid of the gastric juice has no time to act upon any germs which it may contain. For this reason contaminated water is a more obnoxious carrier of disease than impure milk. All the greater, then, is the reason for insuring that our water-supply is above suspicion.

It is commonly said that the free consumption of water at meals is apt to delay digestion by diluting the gastric juice. This statement is not well grounded. Water is itself a slight, though unimportant, excitant of gastric secretion, and experiment has shown¹ that even in quantities of $\frac{1}{2}$ litre (about a pint) it does not in any way affect the rapidity of digestion. Even 1 litre produces only slight slowing, while it requires quantities of $1\frac{1}{2}$ litres (about 3 pints) to produce any marked effect.

On the other hand, it must be remembered that water may actually hasten the digestion of some foods by softening them and favouring their reduction to a state of pulp, while hot water is, as we have seen, a powerful stimulant of the stomach movements.

On the process of *absorption*, water does not seem to exercise any very marked effect, for even on a dry diet the solid constituents of the food entered the blood with their accustomed freedom (Dennig). Any influence which it may exert, however, is probably a favourable one.

INFLUENCE OF WATER ON METABOLISM.

The influence of water on the chemical processes of the body would seem to be very slight. It was formerly believed that an increased consumption of water was accompanied by an increased waste of the nitrogenous tissues. This is now regarded as an error. Any increased excretion of nitrogen which a free consumption of water entails is now ascribed, not to an increased breaking-down of the body substance, but to a washing-out of the tissues and the elimination of waste matters loitering in them.² This eliminative function of water is one of the first importance. It indicates the

¹ Fleischer, *Berliner Klin. Wochens.*, 1882, xix, 97.

² See R. O. Neumann, *Archiv. f. Hygiene*, 1899, xxxvi, 248.

necessity for a free supply of that fluid in such diseases as gout, diabetes, and fevers, and in cases in which the excretory power of the kidney is deteriorated.

VARIETIES OF WATER.

A good drinking water should have little or no colour, no odour, a pleasant, fresh taste, and should contain only a moderate amount of solid matter, $8\frac{1}{2}$ grains per gallon being a good average. A tumblerful of ordinary London water contains only about one grain of solids. A wholesome water should contain very little organic matter, and that should be of vegetable origin, and if it has anything like a large proportion of chlorides it should be viewed with suspicion.

The amount of lime salts which drinking water contains is a matter of some importance, and the relative merits of hard and soft water for drinking purposes have been much discussed. It has been maintained on the one hand that hard waters are apt to be productive in those who habitually consume them of such diseases as goitre and stone, while on the other hand it has been said that soft waters may favour the development of rickets. It must be admitted that neither of these contentions is very well founded, but it may be granted that it is well that the water one drinks should not contain more than 15 grains of lime salts in every gallon, and that the sulphate of lime is more likely to be harmful than the carbonate, for in some susceptible persons its presence may excite dyspepsia and diarrhoea.

The fear that the use of soft water may lead to the development of rickets is quite groundless. When one remembers that even a hard water only contains about 0.002 grm. of lime in every 100 c.c., and that an infant requires about 0.32 grm. of lime daily, it will be evident that as a source of calcium for the bones water may be practically disregarded. On the other hand, there is no doubt that soft waters are more liable to become contaminated with lead than those which are richer in lime salts, and in that respect at least soft water may be a source of danger to health.

The dangers of water as a source of infection, owing to its contamination with the germs of disease, have already been mentioned, and one of the reasons for it pointed out. The avoidance of such contamination, and the provision of pure water on a large scale, is one of the most important duties of the Public Health Authorities in any community, but the methods by which these results are to be obtained hardly fall within the scope of this work. One is

frequently, however, asked for advice as to the domestic purification of water, and as to the best means of avoiding the risk of infection from it, especially during epidemics. The reply one should make to such inquiries is quite clear. The *only* sure method of rendering water harmless is by boiling it.¹ It may be objected that this gives the water a flat and insipid taste, but that objection can easily be overcome by subsequent aeration in a gazogene, or by simply shaking up the water with air in a stoppered bottle. The invention known by the name of the **Sparklets Process** is also a very simple and efficient method of aerating water, and so overcoming the flatness produced by boiling. For convenience in out-of-door use and when travelling it surpasses all other methods. The addition of toast, also, to boiled water communicates to the latter the flavour of some of the soluble ingredients of the toast, and has long been in use as a means of overcoming the flatness produced by boiling.

Before leaving this subject, one must also warn the reader against the delusion so often cherished, that the addition of a little wine, or even spirits, to water can kill any germs that are in it, and so render it safe. That is not the case; the proportion of alcohol in the mixture is never high enough to be certain of killing the organisms.

AERATED AND MINERAL WATERS.

Artificial aerated waters, which are now so familiar,² were invented by the distinguished chemist Joseph Priestley in the latter half of the eighteenth century.³ They are made by charging water with carbonic acid gas at high pressure, the gas being derived from the action of vitriol on chalk. Ordinary bottles of aerated water contain 3 or 4 volumes of carbonic acid gas to 1 volume of water; syphons contain more. There is no doubt that this proportion is needlessly high, and has the effect of causing such violent ebullition when the bottle is opened that some of the contents are apt to be lost during the escape of the surplus gas. The only advantage attendant upon this process is

¹ The Berkefeld and Pasteur filters, if used with intelligence and care, may also be depended upon to render water free from disease germs.

² It has been calculated that upwards of 200,000,000 gallons of aerated waters are consumed in the United Kingdom per annum.

³ 'Directions for Impregnating Water with Fixed Air, in order to Communicate to it the Peculiar Spirit and Virtues of Pyrmont Water and other Mineral Waters of a Similar Nature,' Joseph Priestley, London, 1772. For a full account of the history of the subject see 'The Evolution of Natural Mineral Waters,' by William Kirkby (Manchester: Jewsbury and Brown, 1902).

that the gas, as it passes off, withdraws from the water a considerable amount of heat, so that aerated waters are always cooler to the taste than ordinary water kept under the same conditions.

The varieties of artificial aerated waters which call for mention are as follows :

1. *Ordinary Water impregnated with Carbonic Acid Gas.*—The best makers obtain the water from artesian wells, so that it is of great purity. Ordinary water so impregnated is often, but erroneously, described as 'soda-water.' As soda is sometimes entirely absent, it is better to describe it simply as 'carbonated water.'

2. *Aerated Distilled Water.*—In this case the water is distilled prior to being charged with gas. It is therefore entirely free from mineral matter and from all impurities. Examples of such water are sold under the names of 'Puralis,' 'Salutaris,' and 'Globenaris.'¹

3. *Water to which Various Chemical Salts have been added, e.g. :*

Soda water, containing 3 to 5 grains of bicarbonate of soda to the bottle.

Medicinal soda water, containing 15 grains of bicarbonate of soda ditto.

Potash water, containing 15 grains of bicarbonate of potash ditto.

Magnesia water, containing 12 grains of carbonate of magnesia ditto.

Carrara water, containing 5 grains of lime ditto.

Lithia water, containing 3 to 5 grains of carbonate of lithia ditto.

4. *Imitations of Various Natural Mineral Waters.*—One of the best examples of these is seltzer-water, which is intended to be a substitute for the natural water obtained from the Selters spring. Its ingredients are common salt, bicarbonate of soda, carbonate of magnesia, and hydrochloric acid. By the interaction of these constituents an aerated water is produced which 'gives a good imitation of the peculiar mellowness of genuine seltzer.' An analysis of Schweppe's seltzer showed it to contain 1.13 grains of mineral matter per imperial pint, or 0.620 grain per bottle. A tumblerful had an acid-neutralizing power equal to that of 37½ c.c. of decinormal soda solution.

5. *Sweetened and Flavoured Mineral Waters.*—This is the large and popular group which includes lemonade, ginger-beer, *et hoc genus omne*. The basis of their composition is water sweetened with cane-sugar, and rendered tart by the addition of an acid, then flavoured in any way desired, and finally charged with carbonic acid gas.

A bottle of such water contains about 1 ounce of sugar (equal to five or six ordinary lumps). Unless the water is sold as a genuine 'fruit product' the acid added is only exceptionally citric or tartaric; far more often one finds that a mineral acid is used, most

¹ An excellent aerated distilled water is also prepared by Packham and Co., Ltd. (Croydon).

commonly phosphoric, in the form of so-called 'phospho-lactic' or 'phospho-citric' acid. Some makers employ acetic acid. If citric or tartaric acid is used, the amount added is about 10 grains per bottle, and, as a rule, the acidity of a bottle of ordinary mineral water of this class may be reckoned as about equal to that of a tablespoonful of good vinegar.

The following recipes for making mineral waters are taken from the 'Mineral Water Maker's Manual' (1896), and will serve to show the constituents of some of these products:

Lemonade.

Plain syrup,¹ 1 gallon.
Lemon tincture, 4 ounces.
Acetic acid, 4 to 5 ounces.
1 to 1½ ounces to the bottle.

Ginger-beer.

Plain syrup, 3 quarts.
Boiling water, 1 quart.
Oil of lemons, 24 minims.
Acetic acid, 4 fluid ounces.
Tincture of ginger, *q.s.*
1 to 1½ ounces to the bottle.

Orangeade.

Plain syrup, 1 gallon.
Orange tincture, 4 to 6 ounces.
Acetic acid, 4 ounces.
1 to 1½ ounces to the bottle.

Gingerade.

Plain syrup, 1 gallon.
Tincture of ginger, 4 ounces
Acetic acid, 4 ounces.
Bitter orange tincture, *q.s.*
1 to 1½ ounces to the bottle.

Ginger-ale.

Plain syrup, 1 gallon.
Compound tincture of ginger, 4 ounces.
(Or tincture of capsicum, 1 ounce.)
Acetic acid, 4 ounces.
Sugar colouring, ½ ounce.
1 to 1½ ounces to the bottle.

It will be observed that 'lemonade' and 'orangeade' have very little to do with the fruits from which they derive their names. The term 'ginger-beer' or 'ginger-ale' is even more ambiguous. The article so named may have nothing to do with ginger at all, for the requisite degree of sharpness is usually obtained by aid of tincture of capsicum.

Genuine fermented ginger-beer ('stone ginger') is a very different product. The following are its ingredients:

Water	21 gallons.
Sugar	21 pounds.
Bruised ginger	1½ pounds.
Tartaric acid	6 ounces.
Gum arabic	1 pound.
Oil of lemon	½ ounce.
Yeast	½ pint.

As the result of fermentation it usually contains at least 2 per cent. of alcohol, sometimes considerably more.

¹ 10 pounds of sugar to 1½ gallons of water.

NATURAL MINERAL WATERS.

These are obtained from natural springs, and the majority of them are impregnated with carbonic acid gas. The mineral matters which they contain are very various, but the most abundant are common salt and alkaline salts of soda or lime. For ordinary table use a water must not contain more than 1 per cent. of mineral matter, for above that one begins to get the specific effect of its salts.

The following table contains a description of the natural table waters most largely used in this country, and the results which were obtained from a comparison of their respective acid-neutralizing powers:

Water.	Mineral Matter in an Imperial Pint (in Grms.).	Mineral Matter in a Bottle (in Grms.).	Acid-neutralizing Power of 250 c.c. (=1 tumblerful), expressed in c.c. of Decinormal Caustic Soda.	General Description and Remarks.
Apollinaris ¹	2·27	1·40	91·8 c.c. $\frac{N}{10}$ NaOH	From spring in valley of Ahr (Rhenish Prussia). An alkaline, highly aerated, and slightly chlorinated water. Chief constituents: sodium chloride and carbonates of soda, lime, and magnesia.
Rosbach ..	1·05	0·61	29·3 c.c.	From spring near Homburg. Mildly alkaline; well aerated; lightly mineralized; containing about 1·2 grammes of sodium chloride and 0·5 grammes of earthy carbonates in a litre.
Johannis: ..	1·58	0·95	31·8 c.c.	Produced at Johannis springs (Zollhaus in Nassau). Mildly alkaline and well aerated. Chief salts are carbonates of lime, soda, and a small amount of sodium chloride. A lithiated Johannis is made from this, containing 1 grain of bicarbonate of lithia per bottle.
Perrier ..	0·22	—	15·0 c.c.	A lightly mineralized and well-aerated natural water. The chief salt present is bicarbonate of soda. Obtained from springs at Les Bouillens, Vergèze, in France.

¹ For a fuller description of this water see the *Lancet* ('Some Points concerning Natural Mineral Waters in General and Apollinaris Water in Particular'), January 30, 1904.

Others are :

Vichy (État), with 8 grammes solids per litre (5 grammes bicarbonate of soda). It has a high acid-neutralizing power, 250 c.c. = 268 c.c. decinormal acid, but cannot be regarded as a water adapted for use in health.

St. Galmier, which is largely used in France, has 2·8 grammes solids per litre, chiefly earthy bicarbonates.

Contrexéville (Pavillon) has 2·3 grammes solids of a similar nature, and is only slightly gaseous.

Sparkling Malvern is a pure natural water derived from the Malvern springs. It has 1·8 grammes of solids per litre (0·866 gramme per bottle), including 1 gramme of sodium carbonate and 0·75 gramme of sodium chloride.

Seltzer (Nieder-Selters, in Nassau) has 3·6 grammes solids per litre, consisting of 2·24 of sodium chloride and 1·3 of carbonates.

Adonis is a mildly alkaline water, containing 2·3 grammes sodium bicarbonate per litre. It is soft and well aerated, and is derived from springs situated in the Belgian Ardennes.

Sinaro is a natural sparkling water derived from springs near Wiesbaden, Nassau. Its chief mineral ingredients are the bicarbonates of calcium and sodium.

USES OF MINERAL WATERS.

What dietetic advantages are obtained from the impregnation of water with carbonic acid gas? Apart from the pleasant, sharp taste which such water possesses, one finds that carbonic acid gas is an undoubted aid to digestion. Indeed, it may be said that the mineral waters stand alone among beverages, in that they actually promote the *chemical* processes of digestion by causing an earlier and more abundant secretion of gastric juice.¹ Not only is this the case; carbonic acid acts as a stimulant to the movements of the stomach, and so aids the mechanical processes of digestion also, while the bubbling up of the gas through the stomach contents doubtless facilitates their disintegration.

There are cases, however, in which such waters should be avoided. Carbonic acid gas is rapidly absorbed from the stomach into the blood, and where that fluid already contains an excess of the gas, as it does in cyanosis, it may be well not to run the risk of adding to it. The mechanical distension of the stomach, too, which the escape of the gas induces, may be harmful in dilatation of that organ, and in other cases may hamper a weakened heart by causing the fundus of the stomach to press up against it. The use of mineral waters should also be avoided in cases in which the appetite is much depressed, for the carbonic acid gas, by lowering the sensibility of the stomach nerves, may still further impair the desire for food.

Unfortunately, it cannot be justly claimed for the aerated waters that they are always sterile. Carbonic acid gas is *not* fatal to

¹ Penzoldt, 'Die Wirkung der Kohlensäure auf die Magenverdauung,' *Deut. Archiv. f. Klin. Med.*, 1902, lxxiii. 200.

organisms, with the exception, perhaps, of the cholera bacillus. On the other hand, the mineral waters supplied by the best makers are usually prepared from water obtained from artesian wells, and on that account are likely to be free from the germs of disease. The distilled aerated waters are also beyond reproach in this respect, but they should not be taken in large quantities unless along with food, for there is reason to believe that distilled water may have injurious local effects in the stomach, and lead to nausea and vomiting by destroying its surface epithelium.

The question of *natural versus artificial mineral waters* must be decided entirely in favour of the former. For one thing, the natural waters do not contain any excess of gas, and a larger proportion of what they do contain is present in a combined form than is the case with the artificial waters. Hence their gas is given off more slowly, and they remain longer brisk, and are less apt to lead to sudden distension of the stomach. The following experiment bears this out¹:

	<i>Natural Water.</i>	<i>Artificial Water.</i>	
Gas evolved ..	480 c.c.	760 c.c.	} Bottle opened and exposed for half an hour.
Gas remaining ..	1,010 c.c.	723 c.c.	
Total ..	1,490 c.c.	1,483 c.c.	

There is also reason to believe that the effects of the salts in natural mineral waters are such as cannot be obtained from any artificial imitation of them. The reasons for this have been discussed by Koeppe.² He attributes it to the fact that the natural waters contain traces of many salts which are not present at all in the artificial waters, and which are yet not without effect on the body. Being formed under pressure, too, the natural waters contain double salts, the physical effects of which are not comparable to each salt taken separately, for each salt has its own partial pressure, while for any given degree of concentration one finds fewer dissociated 'ions.' This is not without influence on the physical processes of osmosis, and as a matter of fact it has been found that more mineral matter is absorbed in a given time by the intestine of a dog from a natural than from an artificial water.

The slight alkalinity of some of these waters renders them useful additions to the more acid wines, for the inhibitory action of the latter on the saliva is thereby corrected.

The sweetened mineral waters, such as lemonade, are apt to dis-

¹ Analytical Reports, *Lancet*, August 8, 1891.

² See footnote, p. 285, and Dr. Brasch, *Zeit. f. Diät. und Physik. Therapie*, 1900, iii. 683.

agree with the stomach and produce 'acidity,' both by reason of the acid which they contain, and also from the action of their sugar on the secretory processes in the stomach, and perhaps also by fermentation. On the other hand, it must be remembered that such beverages are by no means devoid of nutritive value, for a bottle of one of them contains enough sugar to yield nearly 115 Calories of energy to the body ; and their refreshing influence in fatigue may also be explained by reference to the value of sugar as a food in exhaustion (see p. 282).

CHAPTER XVIII

TEA, COFFEE, AND COCOA

IN dealing with these beverages, it will be convenient to take up the history, mode of manufacture, and chemistry of each of them separately, and then to consider their action on digestion and their uses in the diet together.

TEA.¹

1. *History*.—Tea was introduced into Europe by the Dutch East India Company in the year 1610. As its price was at first ten guineas a pound, it can be readily imagined that it grew but slowly in popularity, and even in 1660 we find Pepys writing in his Diary: ‘I sent for a cup of tee, a China drink, of which I had never drank before.’ By the beginning of the last century the annual consumption had risen to 1½ pounds per head of the population, and now it amounts to about 6·6 pounds per head. In Great Britain, indeed, we consume more than all the European countries put together, about 800,000 pounds of tea, or 5,000,000 gallons of the beverage, being used daily. It is only in Australia, where tea is so largely used in the Bush, that the consumption surpasses that of this country, amounting as it does to 9 pounds per head of the population annually.

Up to the year 1862 nearly all our tea was obtained from China, the imports from that country reaching their maximum in 1879. Since that time the consumption of China teas has rapidly declined, their place being taken by Indian tea, and, since 1880, by teas grown in Ceylon. The proportion of China tea is now less than 12 per cent. of the total import.

2. *Mode of Manufacture*.—Tea was originally obtained from the leaves of the *Thea chinensis* and *Thea assamica*, both of the *Camellia*

¹ I am indebted for much valuable information on the subject of tea to the following, among other publications: Bannister's Cantor Lectures, 1895; A. G. Stantor, *Journal of the Society of Arts*, January 25, 1890; Prescott, *Popular Science Monthly*, xx. 359, 1882.

order; but many hybrids are now used for tea production. The plant 'flushes,' or sends out young shoots, four times in the year, and is 'picked' at each 'flush.' In China and Japan the best tea is obtained from the first 'flushing,' but in India and Ceylon this is not the case.

The varieties of tea are named according to the different leaves from which they are produced (Fig. 28). The young shoot has two small leaves at its tip which contain least fibre and most juice, and therefore produce the finest sort of tea. In India and Ceylon, tea produced from these leaves is called 'flowery' and 'orange' 'Pekoe,' or, if the leaves are still smaller, 'broken Pekoe.' The tea produced from a somewhat larger leaf just below this is called 'Pekoe'; the next largest leaves produce 'Souchong'; the leaves below that, 'Congou' (though these are not often picked now); while a still coarser leaf near the base of the shoot used to yield 'Bohea,' which has now, however, almost disappeared from commerce.¹

In China a slightly different nomenclature is used, the whole end of the young shoot, with its cluster of leaves, going to form 'Pekoe,' while the leaves below that are used for the production of 'Souchong.'

It should be noted also that the term 'Congou' is often applied in the retail trade to blends, while 'Pekoes' and 'Souchongs' are unblended teas.

The treatment of the leaves after they are picked varies according as black or green tea is to be produced.

For the production of **black tea**, the leaves are 'withered,' then rolled till they become soft and 'mashy,' the object of this being



FIG. 28.—YOUNG SHOOT OF TEA PLANT (AFTER MONEY).

a, Flowery Pekoe; *b*, Orange Pekoe; *c*, Pekoe; *d*, Souchong (first); *e*, Souchong (second); *f*, Congou; *H*, Bohea; *a* and *b* (mixed), Pekoe; *a*, *b*, *c*, *d*, and *e*, Pekoe-Souchong.

¹ 'Pekoe' is derived from 'poco,' the hair or down on the young buds; 'Souchong' means 'little sprouts'; and 'Congou' signifies labour, from the care required in the subsequent treatment of the leaves. It should be noted that to a large extent the varieties or grades of tea described above have now become mere commercial terms, with little relation to any particular leaves.

to break up the fibre and cells of the leaf, and liberate the constituents, so that they are afterwards more easily extracted, and then allowed to ferment. During the process of fermentation, some of the tannic acid in the leaves appears to be oxidized and converted into less soluble forms, while more essential oils seem to be produced, and a certain amount of bitterness developed. After fermentation is complete the leaves are 'fired' in a drying-machine.

For the production of **green tea**, the fresh leaves are withered in hot pans at a temperature of 160° F. (Chinese method), or steamed (Japanese method); then rolled to break them up and liberate their juices; then 'fired.'

It will be observed that the chief difference between black and green tea is that the former is fermented, while the latter is not; and one of the main results of fermentation seems to be to render the tannic acid less soluble, so that, as we shall shortly see, an infusion of green tea contains more tannin than an infusion of black.

In former days a good deal of so-called green tea was really made in the same way as black, and subsequently 'faced' with Prussian blue or indigo to give it the proper colour; but I am informed that this does not take place now to any important extent.

We have seen that the quality of teas varies with the age of the leaf from which they are prepared, the younger leaves yielding the finest tea. Apart from this cause of variation, teas show marked differences according to the country and district in which they are produced.

Chinese teas have the most delicate flavour of any, but are rather lacking in 'body'; they are also devoid of any marked astringency.

Indian teas, and especially those produced in Assam, have the greatest degree of 'body' and astringency. This makes them powerful teas, suited rather for blending with milder varieties than for drinking alone.

Ceylon teas have plenty of body, and a rich and peculiar flavour, but have not so much strength or pungency as the Indian varieties.

According to the district in which they are produced, **Chinese black teas** may be divided into:

1. Monings, from North China, with a small and delicate leaf and a peculiar malty flavour.
2. Kaisows, from South China, the so-called red-leaf teas, because the original teas grown in this district had a reddish leaf.

3. Oolongs, from Formosa, pungent and slightly bitter, yielding a pale infusion, and chiefly used for purposes of blending.

4. Scented orange Pekoe and scented Caper come from the Canton district, and yield a pale, strong infusion with an aromatic flavour, for which reason they are used to give bouquet to blends. Caper is really an unfermented tea, highly fired, and standing intermediate between the black and green varieties.

Of **Indian black teas** those from the Darjeeling district are best, being less rough and astringent than those from Assam, and well adapted for drinking alone. It should be remembered that most black teas in the market are really blends of Indian, Ceylon and China in different proportions.

Most **green teas** come from North China and Japan, the latter yielding the best. Very little is produced in India.

The chief varieties of green tea are Young Hyson¹ and Gunpowder, the former corresponding to a Souchong among black teas, and the latter to Congou.

In judging a tea, professional tea-tasters are guided by the nature of the liquor and the characters of the infused leaves or 'out-turn.'

The infusion should be of a reddish-golden colour, pungent in flavour, but not too bitter or astringent, and not 'thin' or 'hard.'

The infused leaves should be of a bright coppery tint, and evenly extracted, so that some do not look darker than others; they should be uniform in size, and after five minutes' infusion should not be completely unrolled. There should not be too much stalk mixed with the leaves.

3. *Chemical Composition of Tea.*—The following analyses of two typical varieties of tea are given by Bannister:²

					<i>Congou, at 2s. 10d. (Typical Black Tea).</i>	<i>Young Hyson, at 3s. (a Typical Green Tea).</i>
Water	..	..	..	..	8.20	5.96
Caffeine	..	..	..	..	3.24	2.33
Albumin (insoluble)	..	..	..	..	17.20	16.83
„ (soluble)	..	..	..	..	0.70	0.80
Alcoholic extract	..	..	..	..	6.79	7.05
Dextrin	..	..	..	..	—	0.50
Pectin and pectic acid	..	..	..	..	2.60	3.22
Tannic acid	..	..	..	..	16.40	27.14
Chlorophyll and resin	..	..	..	..	4.60	4.20
Cellulose	..	..	..	..	34.0	25.90
Ash	..	..	..	..	6.27	6.07

¹ Young Hyson = Yu-Chien, 'before the rains.'

² Cantor Lectures, 1890.

Of these ingredients, the most important are the alkaloid **caffeine** (also called theine) and **tannic acid**; for these, along with a small proportion of volatile oil ($\frac{1}{2}$ per cent.), are the ingredients to which the chief effects of tea on the body are due. The importance of the caffeine and tannic acid is so great that it may be well to bring forward some further and very exact estimations of these ingredients in different teas which were made by Allen:¹

<i>Description of Tea.</i>				<i>Tannic Acid.</i>	<i>Caffeine.</i>
Ceylon, whole leaf (Pekoe)	..	..	..	13.01 per cent.	3.85 per cent.
„ broken leaf	..	..	..	12.31	4.03
Assam, whole leaf (Pekoe)	..	..	..	10.08	4.02
„ broken leaf	..	..	..	11.33	4.02
Java Pekoe	..	..	..	12.93	3.75
Kaisow, red leaf	..	..	..	11.35	3.41
Moning, black leaf	..	..	..	11.76	3.74
Moyune Gunpowder	..	..	..	12.95	2.89
Natal Pekoe Souchong	..	..	..	9.90	3.08

Indian and Ceylon teas are richer in all the chief ingredients (caffeine, tannic acid, and volatile oil) than China teas. Green tea is richer in tannic acid than black, but the amount of caffeine in the two is almost the same. The following table² (from analyses by Mr. Y. Kozai in Japan) shows the difference in composition between green and black tea produced from the same leaves:

				<i>Original Leaves.³ Per cent.</i>	<i>Green Tea. Per cent.</i>	<i>Black Tea. Per cent.</i>
Crude protein	..	..	..	37.35	37.43	38.90
„ fibre	..	..	..	10.44	10.06	10.07
Ethereal extract	..	..	..	6.49	5.52	5.82
Other nitrogen-free extract	..	..	..	27.86	31.43	35.39
Ash	..	..	..	4.97	4.92	4.93
Caffeine	..	..	..	3.30	3.20	3.30
Tannic acid ⁴	..	..	..	12.91	10.64	4.89
Soluble in hot water	..	..	..	50.97	53.74	47.23
Total nitrogen	..	..	..	5.97	5.99	6.22
Albuminoid nitrogen	..	..	..	4.11	3.94	4.11
Caffeine	..	..	..	0.96	0.93	0.96
Amido	..	..	..	0.91	1.13	1.16

The table shows quite clearly the reduction in tannic acid which the process of fermentation brings about in black tea.

Scott Tebb⁵ compared the amounts of tannic acid and alkaloid extracted from different forms of tea (8 grammes of the tea being infused with 600 c.c. of boiling distilled water for five minutes) with the following results:

¹ 'Commercial Organic Analysis,' vol. iii., part ii.

² See United States Department of Agriculture, Division of Chemistry, Bulletin 13, 1892.

³ Dried at 105° C.

⁴ As gallo-tannic acid.

⁵ 'Tea and the Effects of Tea Drinking' (London: T. Cornell and Sons, 63, Borough Road, S.E.).

Class of Teas.	Number of Analyses.	Per Cent. Extract.	Per Cent. Alkaloid.	Per Cent. Tannin.
Indian	18	26·11	2·84	7·43
Ceylon	12	26·04	2·68	7·85
China	13	22·12	2·40	6·08

An analysis of the teas most widely consumed in London Restaurants gave the following results :

RESTAURANT TEAS.

(Infusion of 8 grammes with 600 c.c. of boiling distilled water for five minutes.)

No.	Description and District.	Retail Price Per lb.	Per Cent. Extract.	Per Cent. Alkaloid.	Per Cent. Tannin.	Proportion of Tannin Corresponding to 2·8 per cent. Alkaloid.
1	"China" Tea	2s. 2d.	20·20	2·51	4·85	5·41
2	Ordinary Black Tea	2s. 2d.	25·60	2·04	9·03	12·39
3	"China" Tea	2s. od.	20·06	2·15	3·02	3·93
4	Ordinary Black Tea	2s. od.	27·90	2·69	9·74	10·13
5	"Russian" Tea	2s. 6d.	23·50	2·30	5·36	6·52
6	Ordinary Black Tea	2s. 8d.	24·60	3·02	6·03	5·59
7	"China" Tea	2s. 4d.	24·50	2·22	5·85	7·37
8	Ordinary Black Tea	2s. 2d.	28·31	2·72	8·44	8·69

The composition of the infusion is of much greater practical importance than that of the leaves from which it is made.

If tea be infused for five minutes in the usual way, about 25 per cent. of the weight of the leaf goes into solution. In making a large teacupful of tea (about 150 c.c., or $\frac{1}{4}$ pint), 5 grammes (about $\frac{1}{8}$ ounce) of dried leaf are usually employed, and a cupful of such tea contains in solution about 15 grains of solid matter. The bulk of this is made up of gummy matters, extractives, etc., but the most important ingredients are the caffeine, and tannic acid.

The caffeine is so soluble that it is practically all dissolved out of the leaf immediately infusion has begun.¹ With tannic acid this is not the case. There is certainly less tannic acid after three minutes' infusion than after five, and less after five than after ten; but beyond that one does not find much increase, for by that time practically the whole of the soluble matters have been extracted from the leaf. The following experiments bear upon this point:

¹ The caffeine in the infusion is combined with tannin in the form of caffeine tannate, in the proportion of one of caffeine to three of tannin (see 'The Chemistry, etc., of a Cup of Tea,' *Lancet*, ii., 1911, p. 1573).

Hughes¹ found the following proportions of tannic acid extracted in different times :

				<i>Five Minutes' Infusion.</i>	<i>Thirty Minutes' Infusion.</i>
Assam ..	..	..	10	35 per cent.	14.76 per cent.
Ceylon ..	..	..	8	60 "	10.88 "
China ..	..	..	7	80 "	9.40 "

Hale White² found :

				<i>Three Minutes' Infusion.</i>	<i>Fifteen Minutes' Infusion.</i>
Finest Assam ..	..	..	11	30 per cent.	17.73 per cent.
" China ..	..	..	7	77 "	7.97 "
Common Congou	..	..	9	37 "	11.15 "

(The figures represent percentage of tannic acid in weight of leaf used.)

The following results were got by Dittman :

				<i>Caffeine. Per cent.</i>	<i>Tannic Acid Per cent.</i>
China tea (8 samples)	{	5 minutes' infusion ..	..	2.58	3.06
		10 " " "	..	2.79	3.78
Ceylon .. (6 ")	{	5 " " "	..	3.15	5.87
		10 " " "	..	3.29	7.30
Indian .. (12 ")	{	5 " " "	..	3.63	6.77
		10 " " "	..	3.73	8.09

It will be observed that the proportion of tannic acid is much more affected by the length of infusion than that of caffeine.

Finally, one may quote the experiments of Green,³ in which 420 c.c. of boiling distilled water were poured on 3½ grammes of tea, and infusion carried on under a cosy for from five to forty minutes, with the following results as regards the composition of the beverage :

				<i>Five Minutes Infusion. Per cent.</i>	<i>Ten Minutes' Infusion. Per cent.</i>	<i>Twenty Minutes' Infusion. Per cent.</i>	<i>Forty Minutes' Infusion. Per cent.</i>
Extract ..	..	..	21	7	25.3	26.8	28.1
Caffeine ..	..	..	1	1	1.3	1.16	
Tannic acid ..	..	..	6	8	8.5	11.7	16.3
Nitrogen ..	..	..	1	11	1.16	1.11	1.04
Ash ..	..	..	3	52	4.09	4.15	4.48

All these experiments agree in showing that the longer tea is infused the higher is the proportion of tannic acid dissolved out, while the proportion of caffeine, on the other hand, is but little affected. From this, the practical inference is that, if one wishes to avoid having much tannin in tea, one should infuse it for as short a time as possible.⁴

The writer has made a number of experiments with the view of determining the amount of caffeine and tannic acid present in an

¹ *Journal of Society of Arts*, January 25, 1895.

² *Brit. Med. Journ.*, 1889, i. 91.

³ Thorpe's 'Dictionary of Chemistry.'

⁴ It has been suggested by the *Lancet* (December 2, 1911) that if a good tea be infused for not longer than five minutes all the caffeine and tannin extracted will be in the form of caffeine tannate, which is free from the injurious effects of free tannic acid, and is probably devoid also of the ordinary pharmacological effects of pure caffeine.

ordinary teacupful of tea infused in the usual way. The results are contained in the following tables :

CAFFEINE IN TEAS.¹

<i>Tea.</i>	<i>Caffeine in Grammes per 150 c.c.</i>	<i>Grains per Teacup.</i>
Ceylon Pekoe	0.0787	1.21
Fine Darjeeling	0.0751	1.05
Common Congou	0.0745	1.14
Moyune Gunpowder (green) ..	0.0645	0.99
Imperial Gunpowder	0.0590	0.90
Household blend	0.0580	0.89
Young Hyson	0.0547	0.84
Fine Moning	0.0510	0.78
Fine Assam	0.0475	0.73

TANNIN IN TEAS.²

<i>Tea.</i>	<i>Tannin as Gallo- tannic Acid per 150 c.c. of Infusion.</i>	<i>Grains per Teacup.</i>
Moyune Gunpowder	0.273	4.20
Young Hyson	0.242	3.72
Imperial Gunpowder	0.227	3.49
Ordinary black blend	0.173	2.66
Fine Darjeeling	0.168	2.58
Good black blend	0.168	2.58
Ceylon Pekoe	0.142	2.18
Lapseng Souchong	0.087	1.33
Fine Assam	0.080	1.23
Fine Moning	0.058	0.89

As a rule, one may say that a teacupful of tea of ordinary strength infused for five minutes contains about 1 grain of caffeine, and twice or three times as much tannic acid.

It may be well to give some practical rules for the proper method of making tea based on the facts as to its chemistry which we have just been considering. This is all the more important as it is comparatively rare to get a really good cup of tea, in spite of the popularity of the beverage. It must be admitted, too, that the fault lies oftener with the method of infusion than with the quality of the original leaf employed.

And, first, the tea should really be *infused*, not boiled or stewed, as is so often the case. The character of the water is of the first importance. The Chinese rule is, 'Take the water from a running stream; that from hill springs is best, river water is the next, and well water is the worst.' The meaning of this is that the water should be well aerated. Prolonged boiling makes it flat by driving

¹ Eight grammes of dry leaf were infused with 300 c.c. boiling water for five minutes. The caffeine was estimated by Allen's method.

² Eight grammes of the dry leaf were infused for five minutes in 300 c.c. of water, and the tannin estimated by Procter's modification of Löwenthal's process.

off the dissolved air. Hence, the water should have just freshly come to the boil. If it is already flat, it is a good plan to pour it into a jug from a height, for this causes it to take up some air again.¹

The water should not be too hard, for the presence of lime salts seems to interfere with the extraction of some of the constituents of the leaf. If only hard water is obtainable, it is a good plan to add a pinch of soda to the teapot. Water which is *too* soft is also bad, for it seems to extract a bitter principle from the leaf. Moderately soft water, therefore, is the ideal to be aimed at.

The quantity of leaf infused demands some attention. The domestic rule of 'a teaspoonful for each person and one for the pot' is an uncertain one, for the weight of a spoonful of tea is a very variable² quantity, depending as it does very much on the tightness with which the leaf is rolled.

Tea-tasters use the weight of a new sixpence ($43\frac{1}{2}$ grains) to $3\frac{1}{2}$ ounces of water, and this, which is a somewhat smaller proportion of tea than that given by the domestic rule, yields a more satisfactory though weaker infusion. It must be remembered, however, that the popular taste is for a strong beverage with a good deal of 'body.'³

The water, as we have seen, should be first brought to the boil, and the teapot should be thoroughly heated, so that the temperature may be maintained: for it is only at the boiling-point that some of the volatile constituents of the leaf, to which the beverage owes its aroma, can be properly extracted.

Infusion should be of limited duration—not more than four or five minutes, for prolonged treatment extracts too much tannic acid, and withdraws from the leaf also bitter substances which are better left behind. In addition to this, prolonged infusion dissipates the volatile oil to which much of the fragrance of a good cup of tea is due. The use of a 'cosy' during infusion does no harm, but as soon as the process is completed the liquor should be poured off into another hot teapot, which may then be kept covered if desired.

The addition of milk or cream, though an outrage in the eyes of

¹ The Chinese directions for preparing the water are as follows: 'The fire must be lively and clear, but the water must not be boiled too hastily. At first it begins to sparkle like crabs' eyes, then somewhat like fishes' eyes, and lastly it boils up like pearls innumerable, springing and waving about.'

² The weight of a caddy spoonful varies from 39 to 87 grains (Smith).

³ For the economical preparation of good tea the thorough crushing of the leaf is of great importance, so that its ingredients may readily be extracted. The powdered tea of Japan is ideal in this respect, and in this country the 'tea tabloids' recently introduced are deserving of a word of praise for the same reason.

connoisseurs, is to be commended on hygienic grounds, for the albuminous matter of the milk tends to throw down some of the tannic acid of the tea in an insoluble form. Sugar does not in any way increase—indeed, it may detract from—the healthfulness of the beverage, but adds considerably to its nutritive value.

All second brews should be avoided, for a single infusion is sufficient to remove from the leaves all the useful constituents of the beverage.

COFFEE.

Coffee was introduced into this country in the year 1652 by a certain Mr. Daniel Edwards, a retired Smyrna merchant, who set up his Greek servant in a coffee-house, the first of its kind in London, in St. Michael's Alley, Cornhill. As a beverage it has never attained the popularity with us that it has won on the Continent, for at the present day we consume less than a pound of it per head of the population annually, whereas in Holland the consumption amounts to 21 pounds. This may be explained partly, perhaps, by the fact that we do not know how to make coffee, but mainly by its great expense when compared with its principal rival, tea.

Coffee is derived from the *Coffea arabica*, originally produced, as the name implies, in Arabia, but now cultivated in many tropical countries. The plant produces three harvests annually, the fruit resembling a cherry, in which the 'coffee-bean' corresponds to the stone. The bean consists of two halves placed face to face and enclosed in a husk. The pulp is softened by fermentation and removed, and the beans, still enclosed in their husk, are dried in the air. The husk is separated by rolling, and the beans are then separated from the delicate parchment-like skin which covers them, and assorted according to size.

Several varieties of bean are found on the market, the chief being as follows:¹

1. *Mocha*.—The genuine beans of this, the finest sort of coffee, are derived from Arabia Felix, but much so-called Mocha coffee is really produced elsewhere, chiefly, perhaps, in Guatemala. Two varieties are met with, 'long berry' and 'short berry.' The former are grayish-yellow in colour, and give a rich, mellow liquor. The latter are pale greenish-yellow, and give a clearer and more delicate infusion (Bannister).

2. *Mysore*.—Here again the name is apt to mislead, for the majority

¹ Bannister's Cantor Lectures, 1890.

of coffees of this name come from Java and Ceylon. The berry is bluish-gray in colour and yields a pure, strong and clear liquor.

3. *Ceylon Plantation*.—The berry is of a pale greenish tint, and yields a clear beverage of full but smooth flavour and fair body. This coffee is largely used for blending.

4. *Costa Rica*.—A bluish-gray berry yielding a strong but rather coarse liquor.

5. *Java*.—A very fine coffee, with large, pale, oblong berries yielding a strong, clear liquor.

6. *Brazil*.—A coffee of peculiar flavour, used chiefly for mixing with other varieties.

In order to prepare the beverage, the berries must first be roasted. The **composition of raw and roasted coffee** is thus contrasted by Bannister:

	MOCHA.		EAST INDIAN.	
	Raw.	Roasted.	Raw.	Roasted.
Caffeine	1·08	0·82	1·11	1·05
Saccharine matter	9·55	0·43	8·90	0·41
Caffeic acids	8·46	4·74	9·58	4·52
Alcoholic extract (nitrogenous and colouring matters) ..	6·90	14·14	4·31	12·67
Fat and oil	12·60	13·59	11·81	13·41
Legumin	9·87	11·23	11·23	13·13
Dextrin	0·87	1·24	0·84	1·38
Cellulose and insoluble colouring matter	37·95	48·62	38·6	47·42
Ash	3·74	4·56	3·98	4·88
Moisture	8·98	0·63	9·64	1·13

The chief physical change which results from roasting is that the berries are rendered brittle and can now be ground. Chemically, one finds that they lose from 13 to 20 per cent. of their weight, the loss consisting in nearly equal parts of moisture and organic matter. The lost organic matter includes about 21 per cent. of the total caffeine and 10 per cent. of the fat.¹ If the coffee is 'over-roasted,' the loss of caffeine may be considerably greater.

The most important substance *produced* in the coffee by roasting is an oil, **caffeol**, to which the aroma of roasted coffee is due, and the fragrance of which is so powerful that one drop is said to be sufficient to scent a whole room.

¹ *Analyst*, p. 287, 1897. See also 'The Chemistry of a Cup of Coffee,' *Lancet*, ii., 1913, p. 1563.

Composition of the Infusion.

From 25 to 35 per cent. of the coffee used in making the infusion goes into solution. This percentage of solubility is about the same as that of tea, but seeing that a much larger quantity of coffee is taken than of tea, the amount of solids per cup is considerably higher in the former than in the latter beverage. If 2 ounces be used to make a pint, a teacupful of the beverage will contain in solution about 4.2 grammes of solids, of which 0.65 is mineral matter. This is supposing the coffee to be filtered. As ordinarily drunk, some suspended matter must also be included.

An analysis which I have made of coffee of the above strength, showed the presence of 1.7 grains of caffeine per teacupful, and 3.24 grains of tannic acid.¹ According to this result, a cup of black coffee contains very much the same amount of caffeine and tannic acid as an equal quantity of tea.² A breakfast-cupful of *café au lait* is composed of about 1 part of black coffee to 3 of milk, and will not, therefore, contain more of the alkaloid than a teacupful of tea.

French coffee demands a special word of mention. It usually contains more or less chicory, and sometimes also some burnt sugar. Chicory is the root of the wild endive, kiln-dried and broken into fragments. The process of drying converts its sugar, of which it may have 10 to 18 per cent., into caramel. There is no reason to believe that chicory is in any way injurious to health, but 1 pound of it is equal in colouring power to 2.8 pounds of coffee, and as a pound of chicory costs 3½d., while a pound of coffee costs about 1s. 5d., it is evident that 3½d. worth of the former is equal, as far as the mere appearance of the beverage goes, to 3s. 11d. worth of the latter. Hence the great temptation to adulterate coffee with chicory, a process which has done much to discourage the consumption of coffee in this country. As a rule, French coffee contains about one-third of its weight of chicory, but sometimes the proportion may be as high as 80 per cent., or even more.

The secret of having good coffee is to make it *strong* and to make it *hot*. We mostly fail in this country by not using enough. Two ounces to the pint is the smallest proportion which will give a good result. It is important that the coffee should be freshly roasted, for its fragrance is quickly dissipated on keeping, and in roasting one must see that the beans are of the same size; otherwise they will be *unequally* fired. For this reason mixing should be carried out after

¹ Reckoned as gallo-tannic.

² Lehmann (*Munch. Med. Woch.*, Nos. 6 and 7, 1913) found that if 15 grammes of coffee are used to make 150 c.c. of the beverage, the solution contains from 0.15 to 0.4 gramme of caffeine.

roasting, and not before. Care also must be taken that the grinder is quite clean, for if any stale coffee is left in it the whole may be spoilt. The water should be just boiling, and infusion may be carried out either in a jug or in a porcelain percolator. For breakfast coffee a mixture of coffees—*e.g.*, half and half Mocha and Plantation—may be used, and the addition of a little ground chicory is liked by some, but for black coffee the latter should always be omitted. Three parts of milk to one of coffee is about the proper proportion for *café au lait*.

Cocoa.

Cocoa was first brought to Europe from Mexico by Columbus in the year 1520. It was known at that time as 'cacao,' but the name got changed with the lapse of time. Although introduced considerably earlier than either tea or coffee, it is only of late years that it has attained any wide popularity, and that chiefly through the energy and enterprise of some of its manufacturers.

The cocoa-plant is the *Theobroma cacao*, the fruit of which resembles a vegetable marrow or cucumber. Embedded in the pulp of the fruit are many seeds, each about the size of a haricot bean, and it is from these that cocoa is prepared. The seeds are separated from the pulp, and placed in heaps for several days to ferment, or 'sweat.' This causes any adherent pulp to become loose, and at the same time modifies the bitterness of the seeds and produces in them a dark colour. They are then roasted, which renders them brittle and loosens the husk, so that the two halves of the seed come out separately on pressure in a machine as *cocoa-nibs*.

The nibs are either sold as such or are ground between hot rollers, which, by melting the fat that they contain, reduces them to a fluid condition. Most of the fat is removed by pressure, and the remainder of the cocoa is then run into moulds, from which it is removed as slabs. For conversion into 'soluble cocoa' or 'cocoa essence' the slabs are again ground down to an impalpable powder.

Various names are applied to different preparations of cocoa. The method of preparing soluble cocoa has just been described; but it should be noted that the term is really a misnomer, for, strictly speaking, there is no such thing as a soluble form of cocoa. All that the term implies is that the powder is so finely divided that it easily remains in a state of suspension when mixed with water. In order to aid the suspension, various methods of treating the cocoa are sometimes adopted. The addition of alkali is a favourite device, especially with Dutch manufacturers. It aids suspension by saponifying and emulsifying the fat, and at the same time softens the

fibre of the cocoa, so that it can form a sort of pulp with water. It also has the effect of deepening the colour of the beverage, and so of making it look stronger. The free addition of alkali is objected to by some as being injurious to health, but it is very doubtful if that can be fairly alleged against it. There are also methods of increasing the solubility of cocoa by the aid of heat, and to these no objection can be urged.

The term *homœopathic cocoa* is sometimes applied to mixtures of cocoa with other substances, such as arrowroot.

Malted cocoa is a combination of pure cocoa with extract of malt.

Navy cocoa is one of the purest preparations of the article, being quite free from husk. The ordinary form contains 20 per cent. of Demerara sugar, whilst the 'soluble' form has 20 per cent. of white sugar and 20 per cent. of arrowroot. Both forms are to be regarded as preparations of chocolate rather than mere cocoa.

Chemical Composition of Cocoa.¹—The general composition of the cocoa-bean is shown in the following table (Bannister):

COMPOSITION OF COCOA.

					<i>Analysis of Raw Trinidad Nibs (Inland Revenue Laboratory).</i>	<i>Analysis of Shelled Fresh Cocoa-beans (Boussingault).</i>
Water	..	..	..	..	5.23	7.6
Fat	..	..	..	..	50.44	49.9
Starch	..	..	..	..	4.20	2.4
Albuminous matter,	soluble	..	..	..	6.3	} 10.9
"	insoluble	..	..	..	6.9	
Astringent principle	..	..	..	..	6.71	0.2
Gum	..	..	..	..	2.17	2.4
Cellulose	..	..	..	..	6.40	10.6
Alkaloid	..	..	..	..	0.84	3.3
Cocoa-red	..	..	..	..	2.20	
Undetermined	..	..	..	..	5.80	5.3
Ash	..	..	..	..	2.75	4.0

The chief ingredient is fat, of which the cocoa-bean contains about half its weight. In the commercial powder, however, there is only about 32 per cent. present, the remainder having been removed by pressure.

Cocoa contains a considerable proportion of nitrogen, but it must be carefully noted that not more than 21 per cent. (Wigner) to 32 per cent. (Stutzer) of this is present as proteins, the rest being in the form of amides. Part also is contained in theobromine.

¹ For much information on this subject and full bibliography, see United States Department of Agriculture, Division of Chemistry, Bull. 13; also a paper by Cohn, *Zeit. f. Physiol. Chem.*, 1895, xx. 1. See also Allen's 'Commercial Organic Analysis,' vol. iii., part ii.

Cohn, indeed, found only 7.9 per cent. of true protein in raw cocoa-beans, using Stutzer's method.

The chief alkaloid found in cocoa is theobromine. Theobromine is known chemically as dimethyl-xanthin, and it is closely related to caffeine, which is methyl-theobromine. Cocoa contains from 1 to 2 per cent. of it, or about as much as there is of caffeine in coffee.

Cocoa contains also some tannin, though probably not of exactly the same form as that found in coffee and tea. Zipperer¹ places the amount at 5.4 per cent. It seems to be combined with a pigment to which the name of cocoa-red is given, but the exact relationship of the two substances has not been fully determined.

Starch is present to the extent of 5.78 to 15.13 per cent. (Ewell).

The proportion of mineral matter is high, amounting in raw cocoa to from 2½ to 3½ per cent. After the fat has been partly removed, the proportion of ash rises to 4 or 5 per cent.; or, if alkali has been artificially added, it may amount to 8 per cent. The ash is strongly alkaline, and in the artificial preparations consists chiefly of potash and phosphoric acid.

The following table contains the results of some analyses which the writer has made of the commonest forms of cocoa in use in this country:

COMPOSITION OF COCOAS.

	Moisture.	Fat.	Nitrogenous Matter (N×6.25).	Non-Nitrogenous Constituents other than Fat.	Ash.
Cadbury's Cocoa Essence ..	3.9	25.2	20.9	45.2	4.8
Fry's Pearl Cocoa ..	7.3	15.8	4.3	71.2	1.4
" Pure ..	5.6	25.6	19.7	43.2	5.9
Van Houten's Pure Cocoa ..	3.0	28.0	20.5	39.7	8.8
Vi-Cocoa ..	6.3	26.9	17.0	43.8	7.0
Schweitzer's Cocoatina ..	4.3	28.2	19.4	41.8	6.3
Rowntree's Elect Cocoa ..	6.5	25.5	18.0	42.2	7.8
Epps's Prepared Cocoa ..	4.9	15.1	6.7	71.8	1.5
Suchard's Cocoa ..	4.7	33.2	18.6	36.7	6.8
Clarnico Cocoa ..	5.1	30.6	22.0	36.1	5.9

Average Composition of a Pure Soluble Cocoa.				Probable Percentage of Nutrients in such a Cocoa.			
Moisture	4	per cent.		Protein	12	per cent.	
Nitrogenous matter ..	20	"		Fat	26	"	
Fat	26	"		Carbohydrates	25	" (?)	
Other non-nitrogenous matter	40	"					
Mineral matter	6	"					

¹ Quoted by Cohn (*loc. cit.*). See also Fraser, *Journ. of Anat. and Physiol.*, 1883, xviii. 13, and Wynter Blyth, 'Foods,' 4th edit., p. 455.

Special attention may be directed to the fact that there is no preparation of pure cocoa which is much poorer in fat than any other.¹

The following additional analyses are by Ewell²:

	Fat.	Fibre.	Cane-sugar.	Ash.	Added Starch.
Fry's Cocoa Extract.	30.95	3.89	—	4.24	None
Schweitzer's Cacoatina	31.13	3.70	—	6.33	"
Van Houten's Coëoa	29.81	4.38	—	8.64	"
Blooker's Dutch Cocoa.	31.48	3.76	—	6.06	"
Rowntree's Cocoa Extract	27.56	4.42	—	8.48	"
" Powdered Chocolate	25.84	1.30	51	1.66	Very little arrowroot
Epps's Prepared Cocoa	25.94	1.51	26	3.15	Much arrow-root
Fry's Diamond Sweet Chocolate	18.60	0.81	55	1.16	Much wheat starch and some arrowroot
London Cocoa (unknown maker)	11.13	2.13	32	2.82	Much arrow-root
Chocolat Menier	21.31	1.10	58	1.40	None

Chocolate consists of ground cocoa from which the fat has not been removed, mixed with white sugar, starch and flavourings, such as vanilla, being often added. The inferior varieties are made from unfermented beans, and therefore have a bitter taste. Good chocolate should melt easily in the mouth, and should not sweat out any sugar in the form of a bloom. The taste also should be free from any roughness or astringency. The white part of chocolate creams consists of a mixture of melted cane-sugar and glucose.

The following are some analyses of chocolate :

	Water.	Nitrogenous Matter.	Fat.	Carbo-hydrate.	Ash.
Chocolat de Santé ³	.. 10.3	12.5	47.1	26.8	3.3
Van Houten's Chocolate ⁴	.. —	3.9	27.5	66.8	1.8
Plain Chocolate ⁵	.. 1.89	7.85 ⁶	21.2	61.9 ⁷	1.9
Milk Chocolate ⁸	.. 1.22	9.39	29.98	57.37	2.04
Plasmon Chocolate ⁸	.. 2.36	18.14	30.36	45.46	2.68

¹ Neumann (*Arch. f. Hyg.*, 1906, lviii. 1) concludes that cocoas with about 30 per cent. of fat are to be preferred on all grounds to those with less. They also have the advantage of remaining longer in suspension than those which are poorer in fat.

² Allen's 'Commercial Organic Analysis,' vol. iii., part ii.

³ Analysis by Atwater and Woods.

⁴ Analysis by the author.

⁵ Analysis in Leyden's 'Handbuch,' i. 109.

⁶ 1.67 = theobromine.

⁷ 7.4 = non-nitrogenous extractives.

⁸ Analysis by Jago (*Fourn. of the Soc. of Arts*, January 10, 1902).

Chocolate was first used as a beverage in this country about 1657. It was very popular in the time of Charles II., and fetched 6s. 5d. per pound.

INFLUENCE OF TEA, COFFEE, AND COCOA ON DIGESTION.

The influence of these beverages on salivary and gastric digestion is, on the whole, unfavourable; of their effects on intestinal digestion we have little exact knowledge; Roberts considers that they are practically nil. Roberts¹ found that tea markedly inhibits the conversion of starch into sugar by the saliva. If there was even 5 per cent. of tea infusion in the digesting mixture, practically no digestion of starch took place. He attributes this result entirely to the tannic acid in the infusion, but found that tea infused for only two minutes had quite as powerful an effect as when the infusion was prolonged for half an hour. He points out that the addition of a pinch of bicarbonate of soda to the teapot completely suspends the inhibitory effect. Aitchison Robertson² confirms these observations as regards tea, but found that coffee had much less influence, and cocoa almost none at all.

The most elaborate investigation of the action of these beverages on digestion in the stomach has been made by Fraser.³ He found that tea and coffee both retard peptic digestion, but the former to a greater degree than the latter, and that Indian tea has a more powerful effect than China. Further, his observations brought out the interesting result that the digestion of different articles is retarded in unequal measure. Thus, the digestion of white of egg, ham, salt beef, and roast beef, was much less affected than that of lamb, fowl, or bread. Coffee, indeed, seemed actually to aid the digestion of egg and ham. He points out that the foods first mentioned are those most commonly eaten at breakfast, the meal with which tea and coffee are usually taken, and he sees in this an unconscious adaptation to obviate any disturbance of digestion. He attributes the retarding effect to the tannic acid and volatile oil which these beverages contain, the caffeine itself favouring digestion rather than otherwise. The addition of milk, it is important to note, largely removed the retarding influence of tea. Fraser also found that tea increased the production of gas from all except the salted foods. Coffee did not do this, and therefore, he says, should be preferred to tea in cases of flatulent dyspepsia. Tea also reduces the acid-absorb-

¹ 'Digestion and Diet,' p. 120.

² Robertson, W. G. A., *Journ. of Anat. and Physiol.*, 1898, xxii, 613.

³ *Ibid.*, 1883, xviii, 13.

ing power of foods; coffee has a similar but less marked effect, while cocoa actually increases it. For this reason cocoa is the most appropriate beverage for patients suffering from the acid forms of dyspepsia.

Cocoa was found to interfere with artificial digestion, owing to the 'clogging' action of its fine particles preventing the free access of gastric juice to the food. It is very doubtful, however, whether it would have any such effect under natural conditions.

The retarding influence of tea and coffee on peptic digestion has been also established by Roberts,¹ Ogata,² and Schultz-Schultzenstein.³ The former is of opinion that the tannic acid only accounts for about one-half of the inhibitory effects exerted by tea. On the whole, they are agreed that coffee has less influence than tea, provided it be of the same strength, but, inasmuch as the former is usually a stronger infusion than the latter, its effects in actual practice are equally powerful.

Apart from their modifying influence on the chemical processes of digestion, it must be remembered that these beverages sometimes affect the stomach more directly. Thus, the tannic acid and other astringent substances met with in strong infusions of tea may act as irritants to the mucous membrane of the stomach, especially if empty; and the same is true to an even greater extent of the caffeol and other products produced in the roasting of coffee. It is in this way that these beverages may sometimes excite or keep up a condition of chronic gastric catarrh. Cocoa also, owing to the large proportion of fat which it contains, is apt to be irritating to some stomachs, especially as the fat of cocoa appears to be one which is rather difficult of digestion.⁴

As regards the practical inferences to be drawn from these experiments and observations, it may be said that in health the disturbance of digestion produced by the infused beverages is negligible. Roberts, indeed, goes so far as to suggest that the slight slowing of digestion which they produce may be favourable rather than otherwise, as tending to compensate for too rapid digestibility which refinements of manufacture and preparation have made a characteristic of modern foods.

In cases where the digestion is enfeebled, on the other hand, and where the ferments are doing their work with difficulty, the presence of these beverages in the digesting mass may make all the difference between failure and success in the process. In such a case, coffee

¹ *Loc. cit.*

² *Archiv f. Hygiene*, 1885, iii, 204.

³ *Zeit. f. Physiolog. Chem.*, 1894, xviii, 131.

⁴ This is true more in the popular than in the physiological sense, for Gardner and Fox (*Biochem. Journ.*, 1919, 13, p. 368) found that cocoa-butter, even in large quantities, is well utilized, and, beyond a slight laxative action, produced no unpleasant effects.

is probably preferable to tea, and cocoa (provided its fat does not prove a disturbance) is better than either. If tea is taken at all, a good China variety should be selected; it should be infused for as short a time as possible, and should be taken with milk.¹ Second cups should be eschewed, and it should be drunk after, rather than during, the meal.

Tea and coffee should both be avoided—but especially the former—as an accompaniment to meals which make large demands on the peptic powers of the stomach, such, for example, as meals containing much meat. For this reason 'high' and 'meat' teas are to be condemned. In chronic catarrh of the stomach, coffee is probably more injurious than tea, but in cases of flatulence the former is to be preferred for the reasons already given. As has been previously pointed out, the irritating effects of these beverages on the stomach are more likely to be manifested when the latter is empty. For this reason, the morning cup of tea may sometimes prove harmful. On the whole, the effects are probably least when the stomach is neither quite empty nor too full, but contains a moderate amount of easily-digested food—a state of things which, one is glad to say, is pretty well true at 'afternoon tea.'

As concerns the length of stay of these beverages in the stomach, the following observations have been made:

200 c.c. (1½ teacups)	of tea remain	..	..	..	..	1½ hours
"	"	coffee remain	..	..	..	1½ "
"	"	cocoa made with water remain	..	..	..	1½ "
"	"	"	"	milk	"	2½ "

In other words, the larger the amount of solid matter which the beverage contains, and the more it approximates to the characters of a true food, the longer does it tend to remain in the stomach.²

There are no available observations on the absorption of tea and coffee. If 110 to 120 grammes (about 4 ounces) of cocoa are taken daily, the loss of nitrogenous matter is about 46 per cent., but of the fat only 4.6 per cent. escapes digestion. The carbohydrates are entirely absorbed.³ If more than 50 grammes (ten teaspoonfuls) were taken at a time, digestion was always upset.

¹ The addition of a little bicarbonate of soda to the contents of the teapot helps to neutralize the injurious effects of the tannic acid. The same result is attained in 'Plasmon tea' by the incorporation of soluble casein with the leaf, which 'detannates' the infusion.

² Miller and Others (*Amer. Journ. of Physiol.*, 1920, 52, 28) found that the evacuation of the stomach was not appreciably delayed by one litre of tea or coffee, but that an equal quantity of cocoa had a retarding effect both upon emptying and upon the rate of development of acidity.

³ Cohn, *loc. cit.* Weigmann found that the fat was absorbed to 94.5 per cent., and the nitrogenous matter to 42 per cent., when 195 grammes of cocoa-powder boiled in water were taken in two days. Neumann (*Arch. f. Hyg.*, 1906, lvi. 1) found that cocoa, when given alone, is not nearly so well absorbed as when it

USES OF TEA, COFFEE AND COCOA.

The action of tea and coffee on the body depends entirely upon the tannic acid, caffeine and volatile oil which these beverages contain. The effects of the tannic acid are purely local, and have already been pointed out, when speaking of the influence of tea and coffee on digestion. The caffeine and volatile oil, on the other hand, have a general pronounced physiological action, to which attention must now be directed.

Caffeine, like alcohol, is a **stimulant**, but, unlike that substance, it exerts its effects upon the central nervous system even more than upon the heart. Physiological experiments have shown that after the administration of caffeine the time occupied by nervous processes is shortened, and reflex excitability is increased. At the same time, it removes the sense of fatigue, and is apt to produce sleeplessness. It is interesting to note that these stimulating effects upon the brain were amongst the earliest of the physiological actions of tea and coffee to be recognised. Tradition has it that in the remote ages there was a holy Asiatic, Prince Darma, who spent his nights in meditation on the Infinite. One night his ecstasy was disturbed by sleep. On waking, he was so enraged at his weakness that he cut off his eyelids and flung them on the ground. On visiting the spot some time later, he found that where each eyelid fell a small shrub had grown up. He infused the leaves of the shrub, and ever afterwards, by simply drinking some of the infusion, he was able to keep sleep at bay. That shrub was the tea plant!

A similar tradition as regards the stimulating effects of coffee is thus recorded by Johnston:¹

‘In antique days a poor dervish, who lived in a valley of Arabia Felix, observed a strange hilarity in his goats on their return home every evening. To find out the cause of this, he watched them during the day, and observed that they eagerly devoured the blossoms and fruit of a tree which hitherto he had disregarded. He tried the effect of this food upon himself, and was thrown into such a state of exaltation that his neighbours accused him of having drunk of the forbidden wine. But he revealed to them his discovery, and they at

forms part of a mixed diet. When added to a mixed diet, it lessens the absorption of nitrogen from the latter, and the less fat the cocoa contains the more marked is this effect. The protein of the cocoa can replace part of the protein in the rest of the diet. Cocoa can therefore claim to rank as a food, although not an important one. In the quantities taken (20 to 30 grams per day) it had no diuretic effect, and the theobromine was only agreeably stimulating. For further experiments on the digestibility of cocoa, see V. Gerlach (*Zeit. f. Physik. und Diät. Therap.*, x, 264), Pincussohn (*Zeit. f. Klin. Med.*, 63, 450), and Zuntz (*Therap. Monatsch.*, 4, 471).

¹ ‘Physiology of Common Life,’ p. 148.

once agreed that Allah had sent the coffee-plant to the faithful as a substitute for the vine.'

As a result of this action on the nervous system, tea and coffee are great aids to mental work, and the former, as De Quincey remarked, will always be the beverage of the intellectual. As a learned Chinaman said of it more than 2,000 years ago:

' It tempers the spirits and harmonizes the mind,
Dispels lassitude and relieves fatigue;
Awakens thought and prevents drowsiness,
Lightens or refreshes the body, and clears the perceptive faculties.'

The vital centres share in the stimulation produced by caffeine, as well as the brain cortex. After its administration, the respiratory movements are deeper and more frequent, and the heart beats more forcibly and rapidly. It is thus an important aid in combating impending paralysis of these centres in cases of coma. Binz, for example, found that dogs which had been rendered comatose by alcohol could be aroused after the administration of coffee. The fact that coffee is an antidote to alcohol is another justification for its use after dinner.

Caffeine, as we have seen, stimulates the heart through the cardiac centre, but it probably has a direct action as well. When administered in the form of tea and coffee, its action is aided by the fact that these beverages are usually taken hot. The increased force and frequency of the heart's action induces a more profuse flow of urine,¹ and so aids in the removal of waste products from the body. This, along with the stimulation of the nervous system and heart, makes tea and coffee of use in some low forms of fever, conditions in which their administration might with advantage be more extensively adopted.

The question has been much debated whether or not caffeine lessens the waste of the body. Some, for instance, have contended that it acts as a kind of drag upon the chemical changes in the tissues, rendering them slower, and so enabling the body to get on with less food than would otherwise be necessary. For this contention, however, there is no satisfactory evidence. Indeed, all experiments go to prove the contrary, namely, that caffeine **tends to increase rather than diminish tissue waste.**² It does not prolong life in starvation, although it may perhaps lessen the *feeling* of hunger. Experiments with the ergograph, too, have shown that tea and coffee are in no sense muscle foods, although they can temporarily

¹ Caffeine appears to have a direct stimulating action on the renal cells as well.

² See Richet's 'Dictionary of Physiology,' article 'Caffeine.'

increase muscular power by abolishing nervous fatigue, so long, at least, as the muscles are not completely exhausted.¹

The action of the volatile oil contained in tea and coffee has not been very fully investigated,² and would appear to be slightly different in the case of the two beverages. It, too, appears to act as a cerebral and cardiac stimulant, and to it, perhaps, some of the unpleasant symptoms, such as headache and giddiness, which afflict those who, like tea-tasters, indulge in large quantities of these beverages are to be attributed.

These oils seem also to have an action upon the bloodvessels which is different in the case of tea and coffee respectively, for the former tends rather to dilate the superficial vessels and render the skin moist, while coffee has an opposite action. It is in this way that tea is said to warm the body when cold, by making the circulation more brisk, and to cool it when heated, by increasing evaporation from the surface.

We may conclude, then, that tea and coffee are in no sense foods, in that they can neither build up the tissues nor provide them with potential energy, though they may perhaps act the parts of lubricants in the machinery of the body by diminishing nervous fatigue. It is no doubt this subjective feeling which has led to the very extended use of these beverages by men in all ages and in all countries.

When we turn to the question as to what extent these beverages can be indulged in without injury to health, one finds it very difficult to give a definite reply. The part played by personal peculiarity and habit in the matter is very great. It has been pointed out, for example, that the usual result of drinking tea and coffee is to produce wakefulness, but yet there are persons who find their use in the evening conducive to sleep. Some people, again, can drink tea quite freely, but are made ill by coffee or *vice versâ*. Facts like these must be recognised although one is unable to explain them, and they make it impossible to lay down definite rules regarding the dietetic use of tea and coffee.

The bad effects usually attributed to an excessive indulgence in these beverages are of two kinds, affecting either the nervous system or the digestion. The increased excitability of the nervous system which they produce may lead to general 'nervousness' (the patient starts, for instance, on the slightest sudden noise, or, as a tea-taster

¹ Schumburg, *Archiv. f. Anat. und Physiolog.*, 1899, Sup. Bd. 289. See also Rivers and Webber, *Journ. of Physiolog.*, 1907, xxxvi. 33.

² The tendency of recent investigations is to minimize the importance of the volatile oil in tea, or even to throw doubt upon its existence (*vide* Scott Tebb, *loc. cit.*).

once put it to the writer, he becomes 'jumpy'), tremulousness, palpitation, loss of sleep, giddiness, and depression. The nervous system in childhood is peculiarly susceptible to these effects.

The disturbance of digestion which tea or coffee, but especially the former, produces is partly due to a direct interference with the chemical part of the process, as already described, but in part also is brought about indirectly through the nervous system. The dyspepsia which results is of the atonic type, digestion being slow, often accompanied by flatulence and attended by a feeling of sinking or depression and disturbance of the heart's action.

Whilst one may fully admit the importance of the part played by tea and coffee in the production of such symptoms, yet the extent to which they prevail has probably been greatly overestimated.¹ It certainly seems an exaggeration to talk, as some people do, of the existence of 'tea drunkenness.' All that one is entitled to infer is that these beverages should be used sparingly by 'nervous' people and by those whose digestion tends to be feeble and slow.

In some cases of gout it is advisable to strike tea and coffee out of the diet, for caffeine is a source of uric acid in the body. Theobromine is so too, but cocoa contains so little of it that it is practically harmless.²

The place of cocoa in the diet is not really very different from that of tea and coffee. An examination of the chemical composition of cocoa might lead one to suppose that it was of considerable nutritive value. But that would be a mistake. Theoretically, cocoa is a valuable food, but practically it is not, the reason being that so little of it can be taken at a time. In this respect it is exactly comparable to many of the beef-extracts already considered. The combination of cocoa with casein—as in **Plasmon Cocoa**—increases the nutritive value of the beverage to a considerable extent.

It takes about 10 grammes ($\frac{1}{3}$ ounce) of cocoa to make a breakfast-cupful of the beverage, and, assuming the average composition given already, this would yield about 40 Calories of energy. It would, therefore, require fully seventy-five such cupfuls to yield the total amount of potential energy demanded of the body daily—obviously an impossible quantity. Of course, if the beverage is prepared entirely with milk and plenty of sugar it becomes an important

¹ For an account of the symptoms which may result from an excessive indulgence in coffee see a paper by Dr. William M. Leszynsky (*Med. Record*, 1901, lix, 41, 70). See also a paper on 'Tea and the Effects of Tea Drinking,' by Dr. W. Scott Tebb (Cornell and Sons, Borough Road, S.E.); and Gouget, 'Le Caféisme et le Théisme' (*Gaz. des Hop.*, 1907, lxxx, 1623).

² Sanitas Health Cocoa contains no theobromine (sold by Battle Creek Sanitarium Co., Ltd., Battle Creek, Michigan, U.S.A.).

food, but that is due to the milk and sugar, and not to the cocoa. Chocolate is of more value. Half a pint of milk and 2 ounces of chocolate yield together fully 400 Calories, and $3\frac{1}{2}$ pints would suffice to supply all the energy and a large part of the building material required in a day.

The action of cocoa on the nervous system is very much less than that of tea or coffee, owing to the small amount of alkaloid which it contains; indeed, it may be practically ignored. The special preparation known as Vi-Cocoa, on the other hand, has an influence on the brain from the addition to it of a certain proportion of *kola*. The latter contains a considerable proportion of caffeine as well as a glucoside (*kola-red*), and it is to these ingredients that its action on the nervous system is to be attributed.¹ *Kola* is said to possess remarkable sustaining qualities, prolonging muscular contraction and abolishing fatigue; but its action seems to be uncertain, and the addition of such a drug to a beverage intended to be used regularly is a practice which can hardly be recommended.

PARAGUAY TEA,²

Paraguay tea or maté belongs to the holly order. It contains a small quantity of caffeine along with a peculiar form of tannic acid, glucosides, choline, and ethereal oils. It yields a pale infusion of somewhat bitter and harsh flavour. It is stated to be even more stimulating and sustaining than tea or coffee, and less apt to cause indigestion and sleeplessness.

Owing to the injurious effects of tea and coffee on the digestion and nervous system in some persons, various substitutes for them in the diet have been proposed. Amongst these are *Ovaltine*, which is composed of malt extract, milk, eggs and cocoa, and which contains a considerable percentage of lecithin. It contains 12.3 per cent. fat, 60 per cent. of carbohydrates, 13.4 per cent. protein, and 3.5 per cent. ash.³ **Life-Belt Coffee** (coffee from which the caffeine has been extracted) and **Cocacorn** (a combination of acorns and cocoa) are other tea and coffee substitutes. Various **Cereal Coffees**, made from parched grains of barley, wheat, etc., are also prepared, especially in America. One or other of these substitutes is sometimes found of use in replacing tea or coffee when these are forbidden on medical grounds.

¹ See *Brit. Med. Journ.*, 1898, i. 1471; *Food and Sanitation*, February 9, 1895; David Émile, Thèse, Paris, 1894; Labesse, Thèse, Paris, 1897.

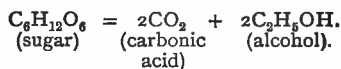
² Paraguay Tea can be obtained from the Apothecaries' Society, Blackfriars, at a cost of 2s. 6d. per pound. Also from the Maté Tea Co., 4, Featherstone Buildings, High Holborn, W.C.

³ *Brit. Med. Journ.*, January 1, 1910.

CHAPTER XIX

ALCOHOL

THE only form of alcohol with which we are seriously concerned in dietetics is ethyl alcohol (C_2H_5OH). It is produced, in all the beverages in which it is found, from the fermentation of sugar by yeast, according to the well-known equation :



We shall subsequently discover that the special characters of different alcoholic beverages depend to some extent on the particular kind of sugar and yeast concerned in the fermentation. It must also be borne in mind that the process of fermentation as carried on in the manufacture of alcoholic drinks is never such a simple affair as the above equation might induce one to believe. Bye-products are invariably produced as well as alcohol, and the nature and amount of these profoundly influence the character of the resulting beverage. Of all alcoholic drinks, however, it remains true that the principal constituent by which they affect the nutrition of the body is ethyl alcohol. It consequently becomes of the first importance for us to study minutely the effects of alcohol on the body, for upon the results of such study our opinion as to the value or otherwise of alcoholic drinks, both in health and disease, must ultimately rest. I propose, therefore, to devote this chapter to a description of the physiological effects of alcohol.

LOCAL EFFECTS OF ALCOHOL.

The local effects of alcohol are those of a chemical irritant. If some strong spirit, such as whisky or brandy, is taken into the mouth, a sensation of burning is produced, owing to the irritation of the nerve endings, and by-and-bye the mucous membrane becomes somewhat corrugated and whitened by reason of the removal of water from its surface cells and the coagulation of their protoplasm.

Repeated local irritation of this sort is the exciting cause of the pharyngitis and gastric catarrh often observed in those who are in the habit of drinking neat spirits, especially on an empty stomach, where the alcohol can come into direct contact with the mucous membrane. The stimulation of the nerves of the mouth brings about reflexly a profuse flow of saliva, and in this way alcohol may promote salivary digestion, for its retarding influence in the chemical transformation of starch into sugar is so slight that it may be neglected.¹

EFFECTS OF ALCOHOL ON DIGESTION.²

Arrived in the stomach, alcohol mixes with the gastric contents, and affects the processes of digestion in several very important directions. The first point to notice is that alcohol has, by itself, surprisingly little influence on the *chemical* processes of digestion. When it is present to the extent of only 1·2 per cent. of the digesting mixture, its influence is rather favourable than otherwise. If the proportion of alcohol is increased to 5 or 10 per cent. the chemical changes of digestion become retarded, but it is only when 20 per cent. of alcohol is present that the process is arrested altogether.³

This immunity of pepsin to the action of alcohol is very striking, and as a consequence of it one cannot regard pepsin wines as irrational products of pharmacy. It is interesting to note that pancreatic digestion is much more sensitive to alcohol, for if the latter be present to the extent of only 2 or 3 per cent., the process is distinctly retarded. But digestion is not merely a chemical process. The movements of the stomach walls play a large part in it also. And here the action of alcohol, in dietetic doses at least, is entirely favourable, for it has a wonderful power of increasing the activity of stomach peristalsis. Binz, for example, found that the administration of eight small teaspoonfuls of brandy at short intervals, for the space of an hour, increased very considerably the rate at which olive oil was discharged from the stomach. He repeated the experiment with similar results in six cases.

Alcohol not merely increases the vigour of the stomach move-

¹ The presence of even 45 per cent. of alcohol does not altogether stop amylolytic action (Roberts). This is confirmed by Aitchison Robertson and by Chittenden and Mendel.

² For an exhaustive study of this subject see 'The Influence of Alcohol and Alcoholic Beverages on Digestion and Secretion,' by Dr. R. H. Chittenden ('Physiological Aspects of the Liquor Problem,' vol. I.; Boston and New York: Houghton, Mifflin and Co., 1903, p. 137).

³ See Buchner, *Deut. Archiv. f. Klin. Med.*, 1881, xxix. 537. See also Chittenden and Mendel, *op. cit. infra*.

ments: it promotes very powerfully the secretion of gastric juice.¹ This it does not merely by directly irritating the nerves of the mucous membrane, but also indirectly by its presence in the blood after absorption. This indirect action of alcohol is of great importance, for it means that even when all the alcohol swallowed has left the stomach, and when any slight retarding influence which it may have exerted on the merely chemical processes of digestion has ceased, it is still able to affect the disintegration of the food by bringing about a more profuse and sustained flow of the digestive juices.²

When one weighs the very slight retarding influence of alcohol on the *chemical* part of digestion against its power of promoting the stomach movements and the flow of gastric juice, one finds that the balance is favourable to digestion, and alcohol must therefore be regarded as a digestive stimulant. In accordance with this, direct experiment on the human subject has shown that alcohol in dietetic quantities, *e.g.*, 30 to 40 grammes of brandy (about two tablespoonfuls), taken before or during meals, actually shortens the time required for the digestion of a meal by about half an hour.³ Red wines were found to have a similar effect.

The net influence, then, of moderate doses of alcohol upon stomach digestion, even in health, is favourable rather than the reverse, while in some conditions of disease its power of exciting the movements of the walls of the stomach and of promoting the flow of gastric juice render it a valuable aid to the digestion of solid food. On the other hand, it is to be noted that in intoxicating doses alcohol interferes with digestion, owing to the general nervous and vascular depression which it brings about.

The importance of these conclusions regarding the influence of alcohol on digestion can hardly be overrated, for they explain much of the benefit which is so often derived from the moderate use of alcohol, even in health, and still more in cases of disease.

Unlike water, alcohol is freely absorbed by the mucous membrane of the stomach. Chittenden and Mendel found that when the pylorus was ligatured 200 c.c. of a 37 per cent. solution of alcohol disappeared from the stomach of a dog in about three hours, and

¹ For some very valuable experiments on this subject see Chittenden and Mendel, *American Journal of the Medical Sciences*, 1896, N.S., iii. 35, 163, 314, 431, and *American Journal of Physiology*, 1898, i. 164. Full references are given in these papers to the results of other workers.

² The gastric juice is not merely increased in quantity. The proportion of its solids and its acidity are raised as well (Chittenden and Mendel).

³ Penzoldt and Wolfhardt, *Munch. Med. Woch.*, 1890, xxxvii. 608.

they add that one may well believe that when 6 or 8 grammes of alcohol are swallowed in the form of wine or beer, 80 to 90 per cent. of it will have entered the blood within half an hour. This is of great importance, for it means that *alcohol requires no digestion*, but is able to pass at once into the blood. Hence much of its value as a rapid restorative, even when all digestive power is in abeyance. Alcohol is not only rapidly absorbed from the stomach itself, but powerfully promotes the absorption of other substances. If, for example, a dose of chloral dissolved in water be injected into a stomach the pylorus of which is occluded, narcosis does not follow, but if even very little alcohol is present the usual soporific results soon set in. It is probably for this reason that sleeping-draughts are often much more rapid in their effects when given along with a glass of whisky or brandy, and the rapid action of medicines in the form of tinctures may be explained in the same way.

The passage of alcohol out of the stomach into the blood is counterbalanced by a flow of water from the blood into the stomach. The 'endosmotic equivalent,' as it is called, of absolute alcohol for animal membranes is 4·13, and this means that for every gramme of alcohol which passes in one direction 4·13 grammes of water pass in the other. If, then, alcohol be administered to a patient with a dilated stomach, the result may be that the total amount of fluid in the organ is ultimately increased.

On the absorption of foods in the intestine alcohol in moderate quantity does not seem to exercise any effect;¹ in other words, one may digest his food better for taking a certain amount of alcohol at meals, but he will not get any more nourishment out of it.

ALCOHOL AS A STIMULANT.

The Latin word *stimulus* means a whip or spur, and a **stimulant** is anything which is capable of spurring on an organ to the performance of more work. As a general rule, it may be said that stimulants act either upon the nervous system or upon the heart, and alcohol is one which affects the latter much more than the former. It is doubtful, indeed, whether alcohol can properly be regarded as a nervous stimulant at all. Any symptoms of increased brain activity which it induces are probably to be regarded as the consequence of an increased flow of blood through the brain rather than as the result of any direct action upon the cerebral cells.

The stimulating action of alcohol upon the heart, on the other

¹ Zuntz and Magnus-Levy, *Pflüger's Archiv.*, 1891, xlix 438, and *ibid.*, 1893, liii. 544.

hand, is one of the greatest importance, and results, in health, not only in a greater frequency of contraction, but also in an increased force of each beat. In disease, however, when the heart is beating rapidly, but feebly and ineffectually, the effect of alcohol is often to diminish the number of the beats while improving their force, and as long as these effects are being produced in a case of acute illness, one is tolerably safe in assuming that alcohol is doing good.

The stimulating effect of alcohol on the heart would appear to be exerted even before absorption has had time to take place, probably through the medium of the nerves of the stomach, which are, as is well known, in very close relation to those which control the action of the heart. Sometimes, indeed, this reflex action is so powerful that it actually leads to a stoppage of the heart altogether. This would seem to be the explanation of those cases of sudden death which occasionally ensue upon the swallowing of large quantities of strong spirits on an empty stomach, as, for example, when a man drinks a pint of whisky for a wager.

After its absorption into the blood, alcohol is able to affect the heart more directly, while at the same time it brings about a dilatation of the bloodvessels on the surface of the body, and so diminishes the resistance to the onward flow of the blood. That this diminution of resistance is not, however, the sole cause of the increased rapidity of the heart's action is shown by the fact that alcohol can raise the pulse-rate even although the bloodvessels have been already allowed to dilate by previous division of the spinal cord. The action on the heart, then, is a direct one.

Of many observations illustrating these effects of alcohol on the circulation I would only cite one by Parkes and Wollowicz, who found in the case of a man that the administration of from 1 to $7\frac{1}{2}$ ounces of rectified spirit daily raised the pulse-rate by ten beats per minute as compared with the period when no alcohol was being taken. They found, moreover, as other observers have found before and since, that this overactivity of the heart was followed by a period of depression in which the beat was both slower and feebler than normal. It is important to bear in mind this after-action of alcohol. It means that the temporary benefits obtained from its stimulating action have to be paid for by subsequent cardiac depression, for alcohol is not, apparently, a food for the heart, but merely a means of enabling that organ to draw for the time being on its reserve of strength. It should be a warning, too, not to begin the administration of alcohol too early in a case of acute disease,

lest one arrives at the period when no further stimulation is possible before the crisis is past.¹

It has been said that alcohol tends to dilate the peripheral blood-vessels. This, indeed, is amongst its leading physiological actions, and one the significance of which it would be difficult to overrate, for it explains many of the apparently contradictory effects of alcohol on the body. There is reason to believe, for instance, that alcohol tends to anæsthetize rather than stimulate the brain, but by dilating the cerebral bloodvessels it may so flush the brain with blood that intellectual activity may be temporarily increased before the anæsthetic effects have had time to manifest themselves. Thackeray is said to have remarked that he got some of his best thoughts 'when driving home from dining out with his skin full of wine.' We need not doubt it, for the statement embodies a physiological truth. It *was* his skin which was full of wine, for alcohol dilates the surface bloodvessels, and along with them those of the brain also, but by the time he got home one may expect that the anæsthetic effects of the alcohol would have begun to exert themselves and the thoughts would have fled. By flushing the brain with blood, alcohol may produce temporary excitement and aid the imagination, but it ends by dulling the edge of the intellect, and is unfavourable to sustained mental work.

Another apparent inconsistency in the action of alcohol which is explained by its effects on the bloodvessels is its **influence on the temperature** of the body. Alcohol, as we shall see immediately, is a fuel, and by its oxidation in the tissues produces heat, just as it does

¹ Since the above was written several more observations on the action of alcohol on the heart and circulation have been published, the results of which, however, are far from uniform. Swientochowski (*Zeit. f. Klin. Med.*, xlv. 284, 1904) found that after the administration of 25 to 100 c.c. of alcohol of 50 per cent. strength the pulse-rate is increased, but slows down again a little in two or three minutes, without reaching the normal again, however, for at least half an hour. For an hour after its administration blood-pressure is lowered. He found no evidence that it really stimulated the heart, but believes that the latter is depressed by alcohol, as are all vital functions. Cabot (*Boston Med. and Surg. Journ.*, 1904, cl. 281) is convinced from his observations on patients that no effect of alcohol upon the heart or blood-pressure is demonstrable, although he does not go so far as to infer that it is useless in disease.

Dixon, chiefly as the results of experiments on rabbits, arrives at the following conclusions (*Journ. of Physiol.*, 1907, xxxv. 346):

1. In moderate doses and well-diluted alcohol has little effect on the rate of the heart; in large doses it slows the heart through the vagus. The failing heart is accelerated by alcohol. When taken by the mouth and in concentration it reflexly quickens the beat.

2. In moderate doses it causes dilatation of the superficial vessels and some slight constriction, which after large doses is followed by dilatation, of internal vessels.

3. In moderate doses alcohol increases the activity and output of the heart.

in a spirit-lamp; but by dilating the surface bloodvessels it causes more heat to be given off by radiation than its own combustion produces, so that the net result is that the temperature of the body is lowered.¹ It is all the more essential to grasp this fact, for the reason that the very flushing of the skin with blood produces a deceptive feeling of warmth, and for that reason alcohol is often taken 'to keep out the cold.' That is a great mistake. Alcohol does not 'keep out the cold,' but lets out the heat of the body, and consequently the consumption of spirits is a very bad means of fortifying one's self to meet a low external temperature, as was found out by the Arctic explorers long ago. By unlocking the surface bloodvessels and allowing of the escape of heat, alcohol often renders great service in the treatment of fevers; but in health the paralysis of the heat-regulating mechanism which it induces may be dangerous, or even fatal, and one finds as a matter of fact that persons who are frozen to death, in this country at least, have

(He suggests that this may be due to its action as a food.) In intoxicating doses it depresses the heart.

4. When administered to animals which show signs of circulatory failure, alcohol raises blood-pressure mainly on account of its effect on the heart. In normal animals and in man, whilst the systolic pressure may rise a little or remain unchanged, the diastolic tends to diminish; in other words, the difference between the systolic and diastolic pressures tends to increase.

Abel ('Physiological Aspects of the Liquor Problem,' edited by John S. Billings; Boston and New York: Houghton, Mifflin and Co., ii, 91) summarizes the experimental evidence regarding the action of alcohol on the vascular apparatus as follows:

1. Alcohol as such, when introduced into the circulation with the avoidance of local irritation, is not a circulatory "stimulant."

2. Alcohol in moderate quantities—say a pint of wine—has no direct action on the heart itself, either in the way of stimulation or depressing it. This statement is based on the results of laboratory experiments extending over short periods of time only, and does not imply that it holds for the steady daily use of alcohol in this quantity.

3. In moderate quantities it has no appreciable effect on the blood-pressure. When a change in this becomes evident it is always in the direction of a fall.

4. By virtue of its local action on mucous membranes and on the brain, alcohol is capable of affecting the several parts of the vascular apparatus in such ways that the term "circulatory stimulant" may be applicable. The most frequent of these indirect effects is a quickening or slowing of the pulse-rate. Such indirect influences must not be allowed to hide the true character of alcohol, which is always depressant in kind.

¹ This only seems to occur in appreciable degree, however, when the alcohol is taken in intoxicating doses. On this point Atwater and Benedict remark: 'The theory that the energy yielded by alcohol is lost by the increased heat-radiation, like the theories that alcohol is not oxidized in the body, and that it prevents normal oxidation of other material, was suggested by observed facts. In each case the facts were suggestive, but not conclusive. Under crucial tests they are found to fail' ('Physiological Aspects of the Liquor Problem,' ii, 297).

usually met with that fate through their having been in a state of intoxication when the cold overtook them.

On the other hand, if one has been already exposed to cold, and the blood has been driven into the internal viscera, and is stagnating there and about to produce congestion, the timely administration of alcohol may save the situation by once more bringing about a proper distribution of the blood.¹ By all means, then, take alcohol on coming indoors when wet or chilled, but carefully avoid it when about to proceed out to meet the frost or rain.

There can be no doubt that prolonged over-indulgence in alcohol may cause the vascular paralysis of which we have spoken to become permanent, whence the bloated look and purple nose of the drunkard. In such a case the beneficial effects which should otherwise be obtained from the administration of alcohol in acute disease are no longer manifested. The heart and bloodvessels have been so often stimulated that they have ceased to respond to the spur, and the patient often pays the penalty with his life.

INFLUENCE OF ALCOHOL ON METABOLISM.

Alcohol is a protoplasm poison or anæsthetic, but is itself easily burnt up in the body. That is the key to the proper understanding of its action on metabolism. Let us see more exactly what the statement means. We have already seen (p. 22) that the cells of the body may be regarded as being bathed in fluid which contains in solution particles of protein, of carbohydrate, and of fat, and we have further learnt that there is reason to believe that these are broken down by the cells with different degrees of facility, protein being most easily destroyed, then carbohydrate, and lastly fat. If now alcohol gets access to the cell and partially paralyzes or anæsthetizes it, the cell will lose its power of breaking down those compounds, such as fat, with which it has, even in a condition of full activity, most difficulty in coping. Alcohol, then, saves fat from combustion; in other words, it is a fat-sparer. It also appears, though with greater difficulty, to be able to spare carbohydrate, but it is more doubtful whether it is ever able so far to paralyze the cell as to destroy its power of dealing with protein. This action of alcohol on cellular activity is quite in keeping with what we know of the effects of other cell poisons. Arsenic, for instance, seems to impair the fat-destroying power of the cells, while there is some reason to suppose that lead interferes with their ability to break down protein, and so

¹ See also Brunton, 'The Physiological Action of Alcohol,' *Practitioner*, 1876, xvi 57, 118.

may predispose to gout, while hydrocyanic acid is the most powerful protoplasm poison known, and by paralyzing the activity of the cells in every direction at once leads to death.

Alcohol, then, certainly spares fat and sometimes carbohydrate, but in so doing it is itself consumed, and yields heat and energy to the body. Of this fact, once much disputed, there is no longer any doubt, and it at once entitles alcohol to rank as a *food*.¹ Careful experiments have shown that the complete combustion of 1 gramme of alcohol in the body yields 7 Calories of energy; in other words, 131 grammes of alcohol will yield as much heat as 100 grammes of fat, which means that 1 ounce of alcohol supplies as much fuel as 1 ounce of butter² (about 200 Calories).

This statement must not be misunderstood. It does not follow from it that alcohol is as good a source of heat in the food as fat. Quite the contrary is the case, for, as we have already seen, by dilating the surface bloodvessels, alcohol may cause more heat to be lost than it is itself capable of producing. Further, alcohol is rapidly burnt up, and the heat which it yields is quickly dissipated, while fat produces heat in a slower and more equable fashion. In large doses the general paralysis of cellular activity which alcohol produces is so great that heat production is diminished at the same time as heat loss is increased, and the final result is a great lowering of the body temperature, which may even amount to 15° F.

There is still less reason to regard alcohol as a useful muscle food. Even granting that it can be oxidized in the muscles in such a way as to be capable of yielding energy, any value which it may possess in virtue of that is seriously counterbalanced by the paralyzing effect which it exerts on nerve cells, dulling the sense of exhaustion which is Nature's warning, so that, as experience has shown, the consumption of alcohol during muscular work tends to hasten rather than delay the onset of fatigue.³

Seeing that alcohol in sparing fat and carbohydrate is itself oxidized, one is not surprised to learn that its administration does

¹ 80 per cent. of fat.

² See Scarborough, 'Alcohol as a Food,' *Yale Med. Journ.*, January, 1910, p. 239.

³ See ergographic experiments by Destree, *Quarterly Journal of Inebriety*, January, 1899; also Schnyder, *Pflüger's Archiv.*, 1903, xciii. 451. Later observations by Rivers ('Influence of Alcohol, etc., on Fatigue'; Edward Arnold, 1908) show that in doses of 5 to 20 c.c. of pure alcohol there is no effect on muscular fatigue; with doses of 40 c.c. the results are inconstant. On the whole, alcohol seems to have a depressing effect on mental work, and a stimulating one on muscular work. The consensus of opinion among Alpine climbers ('Alcohol and Alpinism,' by Dr. L. Schnyder, translated by E. J. Richards; Edinburgh and London: William Green and Sons, 1910) is that alcohol should be avoided during muscular exertion, although it is believed by many to have a restorative effect after the work is over.

not increase or diminish either the intake of oxygen or the output of carbonic acid gas.¹ On the other hand, if the amount of fat or carbohydrate in the diet is already insufficient for the needs of the body, alcohol is able to supplement them by acting as a source of heat. Atwater found that from one-fifth to one-seventh of the total Calories of the diet could be thus replaced by alcohol, and this explains the observation of Hammond, that when he added alcohol to a diet on which he was losing weight the loss was immediately stopped.²

Anstie³ has recorded some striking instances of a similar sort in which alcohol seemed to act as a true food. He kept patients alive during acute illness for many days on nothing but large quantities of brandy, and found that they had not emaciated during that time nearly so much as they would have done if they had been merely living on their own tissues. Nor is this surprising, for the amount of alcohol (12 ounces of brandy) supplied daily was capable of yielding close upon 1,000 Calories to the body.

Much discussion has taken place amongst physiologists as to whether alcohol is or is not a protein-sparer. It would be impossible to summarize the evidence on each side of the question here,⁴ but it may be stated in brief that the results of the latest and most trustworthy experiments tend to show that alcohol undoubtedly possesses some power of lessening nitrogenous waste. Its influence in this respect, however, is far less than that of carbohydrates,⁵ and less even than that of fats, and seems to vary under the influence of conditions which are not fully understood, and to depend also, to some extent, upon the personal peculiarities of the subject of experiment. The point is of some importance, for it has been believed by many that the administration of alcohol has the power of checking the rapid waste of nitrogenous tissue which goes on in fever. Unless, however, the action of alcohol is very different in fever from its behaviour under healthy conditions—a proposition for which there is no real evidence—one is not justified in assuming that it has any appreciable influence in that direction.

As regards the general influence, then, of alcohol on metabolism, we may safely conclude (1) that it is burnt up in the body, sparing

¹ Zuntz, *Fortschr. d. Med.*, 1887, v. 1, and Geppert, *Arch. f. Exper. Path. u. Pharmak.*, 1887, xxii. 367.

² 'Physiological Memoirs,' 1863, p. 47.

³ 'Stimulants and Narcotics,' London, 1864.

⁴ For a full discussion of the subject see 'An Experimental Inquiry regarding the Nutritive Action of Alcohol,' by Atwater and Benedict (*Nat. Acad. of Sciences*, 1902, vol. viii., Memoir 6); also Neumann, *Arch. f. Hygiene*, 1902, xli. 85; Kassowitz, *Pflüger's Archiv.*, 1902, xc. 421; and Goddard, *Lancet*, 1904, ii. 1132, 1162.

⁵ Rosenfeld, however, finds (Abst. in *Maly's Jahres-Bericht Thier-Chemie*, xxxvi. 674) that alcohol has no injurious effect on metabolism, and is a better protein sparer than an equal quantity of sugar.

fat and carbohydrate in the process, but that (2) the weight of evidence is against the view that it has any important power of diminishing nitrogenous waste.

The question next arises, At what rate does the combustion of alcohol in the body go on? Is it so rapid that all of it is decomposed, or is there time for some of it to be eliminated unchanged? The reply to these questions is that much depends on the quantity of alcohol taken. In non-intoxicating doses, exceedingly little, not more than from 1 to 3 per cent. at most, passes off from the body unchanged.¹ If, on the other hand, the quantity consumed be sufficient to produce intoxication, the amount of alcohol which escapes combustion may rise to more than 10 per cent. of the whole dose.

Whenever the proportion of alcohol circulating in the blood becomes greater than the cells can rapidly decompose, its effects as a protoplasm poison become manifest. In their extreme form those effects culminate in intoxication, which is really a condition of cell paralysis, so that the expression 'paralytic drunk' has a truer physiological meaning than those who use it commonly suppose. The brain cells seem to be peculiarly sensitive to the paralyzing action of alcohol, so that the brain is the first to show the effects of an overdose. It is paralyzed from above downwards, the higher centres being affected first. Now, the highest centres are the controlling centres of the brain, and hence loss of control, intellectual, emotional and muscular, is the earliest sign of alcoholic intoxication. It is only in the extreme degrees of the condition that the 'driving centres' of the brain, the centres of organic life which maintain the action of the heart and provide for respiration, become involved in the paralysis, and the condition then is one not merely of intoxication, but of coma, and threatens life itself.

The bad effects of alcohol taken in quantities sufficient to produce intoxication are too apparent to require to be insisted upon. It must be remembered, however, that the habitual consumption of alcohol in quantities which, though insufficient to produce any of the outward and visible signs of intoxication, are yet beyond the immediate oxidizing power of the cells, may end by playing havoc with the tissues. Here, again, the brain seems specially liable to suffer, probably owing to its being one of the most highly organized and delicate tissues in the body. As the result of chronic alcoholism

¹ See Anstie, 'Final Experiments on the Elimination of Alcohol from the Body,' *Practitioner*, 1874, xiii. 15. See also Binz's 'Lectures on Pharmacology,' and Atwater and Benedict, *loc. cit.*, and Goddard, *loc. cit.*

it becomes the seat of various degenerative changes to which the motor centres seem less resistant than the sensory. I think, too, that one can recognise in the habitual alcoholic a certain degree of paralysis of the moral perceptions, and in special a loss of the sense of truth. Throughout the body generally the presence of even a slight amount of undecomposed alcohol leads to a diminution of the chemical energy of the cells, which interferes with the ordinary course of metabolism, and may result in chronic disease. The metabolism of fat is, for reasons already pointed out, most apt to be interrupted, and hence alcoholism is a common cause of fatty degenerations and an important factor in many cases of obesity. By delaying the decomposition of carbohydrates, it aids in the productions of some forms of diabetes, and there can be no doubt that it plays a large part in that alteration of protein metabolism which seems to be the basis of gout.¹

It seems reasonable, also, to suppose that the excretion by the kidney and other organs of undecomposed alcohol may act as an irritant and bring about changes in structure, which may end in serious interference with the discharge by the affected organ of its normal functions. It is in this way, for example, that the habitual consumption of more alcohol than can be decomposed in the body may produce chronic nephritis. All these considerations bring home to one the very great importance of ascertaining, if only approximately, how much alcohol can be so completely oxidized in the body that there will be none left over to exercise upon the tissues those injurious influences of which we have just been speaking. Experiments carried out with a view of determining this point have shown that 1 to 1½ fluid ounces of absolute alcohol is about the amount which can be completely oxidized in the body in one day, and in such a way that none of its paralyzing or narcotic effects are manifested, and no unchanged alcohol appears in the urine (Parkes).² This quantity of alcohol would be contained in the following amounts of some of the commoner alcoholic drinks:

Brandy or whisky (50 per cent. alcohol)	2 fluid ounces, or 1 glass.
Port, sherry, and other strong wines (20 per cent. alcohol)	5 " " or 2½ glasses.
Claret, hock, champagne, and other weaker wines (10 per cent. alcohol) ..	10 " " = 1 tumblerful.
Bottled beer (5 per cent. alcohol) ..	20 " " = 1 imperial pint.

¹ See also Von Strümpell, 'Ueber die Alkohol Frage vom Aerztlichen Standpunkt,' aus 65ten Versamml. deut. Naturforscher zu Nürnberg, 1893, p. 97.

² Goddard (*loc. cit.*) found that if alcohol was administered to dogs to the extent of $\frac{1}{16}$ of the body weight it was almost completely oxidized. If the same proportion holds good in the human subject, a man of average weight (150 pounds) ought to be able to oxidize about 3 ounces.

Whilst we may admit the probable accuracy of the data on which these calculations are founded, two modifying factors have to be considered. The first of these is the question of idiosyncrasy. There can be no doubt that **personal peculiarity** plays a very large part in determining the amount of alcohol which can be consumed by any given individual without injury to health. Some persons seem to be able to burn up alcohol more rapidly and completely than others, for reasons which do not seem to be connected with any determinable peculiarity of physical organization. Certainly every one must have known persons who were able to go on consuming daily a far larger quantity of alcohol than the standard above laid down, and yet without their health being appreciably impaired by the indulgence. Indeed, when one recalls the drinking exploits of our grandfathers and the prowess of the 'three-bottle men,' one is almost tempted to think that the power of our tissues to oxidize alcohol has actually undergone a decline. Apart from mere peculiarities of constitution, it must be obvious that the surroundings and habits of each individual must affect very greatly the amount of alcohol in which he can indulge with safety. The rapid oxidation which is the result of an active, open-air life, for example, enables an amount of alcohol to be consumed with impunity which would work disastrous consequences in one of sedentary pursuits.

The other factor which must influence any calculation as to the amount of alcohol which can safely be consumed daily is the form and mode in which the alcohol is taken. It will be generally conceded that the same quantity of alcohol is less likely to be injurious if taken in a dilute than in a concentrated form. It must be evident also that an amount of alcohol which would be harmful if swallowed at one time may be free from risk if spread evenly over the day. The danger to be avoided is flooding the circulation at one time with an amount which it is beyond the power of the cells to oxidize.

USE OF ALCOHOL IN HEALTH.

We have seen that one cannot deny to alcohol the right to be regarded as a 'food' in the scientific sense of the term. We have also seen, however, that it cannot be regarded as a food of any great practical importance, for it is merely able to replace a certain amount of fat, and perhaps also of carbohydrate, in the body, while its secondary effects on the nervous and vascular systems counteract, to a large extent, the benefits derived from the production of heat and energy by its oxidation. As a food, also, alcohol is open to the

additional objection of being very costly. Even in Bavaria, the land of cheap beer, it has been calculated that alcohol, in that, its least expensive form, is eight times dearer than bread, from the point of view of the amount of heat yielded.

It has been shown that alcohol is not favourable to the production of sustained muscular effort, and that it may even do harm by paralyzing the sense of fatigue which is the natural check on excessive exertion. Nor can it be said that it is favourable to the production of perfectly healthy brain-work. An interesting book¹ was published a few years ago in which were gathered together the results of the personal experience of leading men in literature, science and art on the effects of stimulants as aids to intellectual work. It is interesting to note that, out of the 124 individuals consulted, none ventured seriously to recommend alcohol as an aid in the performance of mental labour. As Abel has said:² 'He who has mental labour of an exacting kind to perform and he upon whom great responsibilities devolve, is forced, if he would be at his best, to use alcohol as a restorative agent only at the proper season; he must behave to it as he does to many other pleasures and luxuries in his environment.' A census in America yielded much the same result.³

We may conclude, then, that alcohol is an unnecessary article of diet in complete health, although, if used within the limits already indicated, it cannot be said to be harmful, and may even, indeed, be beneficial; for, as Matthew Arnold has said in the book already referred to, 'wine used in moderation seems to add to the agreeableness of life—for adults, at any rate—and whatever adds to the agreeableness of life adds to its resources and power.'

It is in conditions just short of health, however—in old age, overwork and fatigue—that the beneficial effects of alcohol become most marked. They may be traced almost entirely to its favourable influence on digestion, and hence a good rule for the use of alcohol in all conditions short of actual disease is to take it only at meals, and in such quantities as are found to improve the appetite for food and the capacity for digesting it. As regards the form in which it should be used, beer seems most natural for youth, wine in middle life, whilst spirits may be reserved for the aged.⁴

¹ 'Study and Stimulants,' A. A. Reade (Simpkin, Marshall and Co., 1883).

² 'Physiological Aspects of the Liquor Problem,' ii. 165.

³ *Ibid.*, vol. i. See also Stanley Kent, 'Fatigue and Alcohol,' *Lancet*, July 28, 1917.

⁴ In the *Contemporary Review* for 1878 and 1879 there will be found a very interesting discussion of the alcohol question, in which several distinguished physicians and surgeons took part. The opinion of most of them was that the moderate use of alcohol in health is harmless, if not indeed actually beneficial.

USE OF ALCOHOL IN DISEASE.

Just as the effect of alcohol on the digestion is the test of its value in health, so its effects on the circulation and nervous system are the criterion of its usefulness in most cases of acute disease. As long as the efficiency of the heart is improved by its administration, alcohol is doing good. In fever, its power of lowering temperature and its calming influence on the brain are also of use, while it may, perhaps, check somewhat the tissue waste which is so marked a feature of acute fevers, although we have seen reason to doubt this—at least, as far as the nitrogenous tissues are concerned. To this point, however, we shall return in another chapter (p. 484). There are grounds also for the belief that alcohol actually increases the resisting power of the body to the poisons of certain diseases—such, for example, as septic fevers. I am aware that laboratory experiments¹ have shown that rabbits in a state of intoxication are actually less resistant than normal to certain organisms, such as the streptococcus of erysipelas, but the dose of alcohol administered was excessive; and to set against these results we have the clinical

In Dr. Wilks' paper the view that alcohol is essentially a *narcotic* rather than a stimulant is strongly presented, while Dr. Moxon deals in the most interesting manner with its effects on the mental faculties. The conclusions of Dr. Murchison, which are not, however, in complete harmony with those of most of the other contributors, are as follows:

1. A man in good health does not require alcohol, and is probably better without it. Its occasional use will do him no harm; its habitual use, even in moderation, may, and often does, induce disease gradually.

2. There are a large number of persons in modern society to whom alcohol, even in moderate quantity, is a positive poison.

3. In all conditions of the system characterized by weakness of the circulation, the daily use of a small quantity of alcohol is likely to be beneficial, at all events for a time.

Sir James Paget wrote: 'I cannot doubt, with such evidence as we have, that the habitual moderate use of alcoholic drink is generally beneficial, and that in the question raised between temperance and abstinence the verdict should be in favour of temperance.'

On the whole, the views presented by these writers may be regarded as fairly representing contemporary medical opinion on the subject.

The latest authoritative statement on the action of alcohol on the human body is contained in the Report of the Advisory Committee to the Central Control Board (H.M. Stationery Office, 1918). The report is a very judicial representation of our present knowledge, but none of its conclusions conflicts materially with what is set out in the text of this book.

¹ See Abbott, *Journal of Experimental Medicine*, 1896, i. 447. Parkinson (*Lancet*, 1909, ii. 1580), as a result of experiments on the relation of alcohol to immunity, arrives at the following conclusions:

1. Alcohol in small quantities has no action upon the phagocytic activity.
2. It has no action on the phagocytic activity until it is present in 12.5 per cent. strength.
3. Small quantities of alcohol injected into rabbits may stimulate the production of antibodies temporarily.
4. A large dose of alcohol lowers the opsonic index for twenty-four hours.

experience of good observers, who regard alcohol as being actually an antidote to acute erysipelas.

In some chronic diseases, such as diabetes, alcohol is used as a real food to replace a certain amount of carbohydrate in the diet, whilst in others it is chiefly its tonic influences on digestion which one seeks to obtain. We shall have occasion to study its uses in these different directions in detail in subsequent chapters.

5. Continuous moderate doses of alcohol cause a permanent lowering of the opsonic index.

6. The reacting mechanism to vaccines is much less effective in alcoholized rabbits than in normal rabbits; the difference is still more marked when living micro-organisms are used.

CHAPTER XX

ALCOHOLIC BEVERAGES : SPIRITS AND MALT LIQUORS

BEFORE proceeding to the study of the alcoholic beverages in detail, it may be well to describe the different ways in which the amount of alcohol which they contain may be stated. This is all the more important as an inaccurate use of terms may lead to some confusion.

In this country the standard employed is usually what is known as **proof spirit**, and an alcoholic liquor is said to be so much above or so much under 'proof.' Proof spirit is a mixture of alcohol and water, which contains 49·24 per cent. of the former *by weight* (*i.e.*, 100 grammes contains 49·24 grammes alcohol¹), and 57·06 per cent. *by volume* (*i.e.*, 100 c.c. contains 57·06 c.c. alcohol). 'The name *proof spirit* owes its origin to the practice in vogue during last century, of testing the strength of samples of alcohol by pouring them on to gunpowder and applying a light. If the sample contained much water the alcohol burned away, and the water made the powder so damp that it did not ignite; but if the spirit were strong enough the powder took fire. A sample which just succeeded in igniting the powder was called proof spirit' (Perkins and Kipping). Spirits are described as being *over proof* when they are stronger than proof spirit, and *under proof* when they are weaker. Thus, 20 over proof means that 100 volumes of the spirit contain as much alcohol as 120 of proof spirit, and 20 under proof means that 100 volumes only contain as much alcohol as 80 of proof spirit.

Instead of using proof spirit as the standard, it is more convenient to speak of the amount of alcohol as being so much *per cent.* The percentage may further be stated either in weight or in volume. Five per cent. of alcohol *by weight* means, strictly speaking, that 100 grammes of the liquid in question contain 5 grammes of alcohol; but more usually the expression is used for weight *in volume*—

¹ 100 grammes of proof spirit has a volume of about 110 c.c., for shrinkage occurs when water and alcohol are mixed.

i.e., 5 grammes of alcohol in 100 c.c. Five per cent. by volume means 5 c.c. in every hundred, and is equivalent to about 4 per cent. by weight.¹ The percentage of alcohol *by volume* in some of the commoner alcoholic beverages is roughly as follows :

Rum	..	} 43 per cent.	Port	..	25 per cent.	Hock	..	10 per cent
Whisky	..		Sherry	..	21 "	Claret	..	9 "
Brandy	..		Champagne	..	10 to 15 per cent.	Bottled beer	..	7 "
Gin	..					Lager beer	..	4 "

SPIRITS.

Spirits are obtained by the fermentation of various saccharine substances, the alcohol and other volatile bodies produced being separated by distillation. It is this fact of their being the products of distillation which gives to spirits their high alcoholic strength, and distinguishes them from all other alcohol-containing beverages. Almost any substance capable of yielding a fermentable sugar may form the basis of fermentation. Amongst the substances most commonly used in this country are malted and unmalted barley, maize, rice, sugar, and molasses. In some parts of Europe, and especially in Russia, potato starch is largely employed for the purpose. All of these substances yield alcohol on fermentation, but in addition various bye-products make their appearance during the process, and it is to the presence of these that the characteristic flavour of the different spirits is due.

Thus, the bye-products of the fermentation of malted barley give rise to the flavour of whisky, those of molasses to the flavour of rum, and those of the grape to that of brandy. By means of patent stills the bye-products can be almost entirely separated from the alcohol with which they are mixed, and the result is an almost pure form of spirit, the origin of which can scarcely be told, for which reason it is called **silent spirit**. By suitable flavouring the artful manufacturer can make this the basis of almost any spirituous drink.

Amongst the bye-products of fermentation there are usually found alcohols which are higher homologues of ethyl alcohol—e.g., propyl, butyl, and amyl, and to a mixture of these the term **fusel-oil** is often applied. There is some reason to believe that fusel-oil is the product of a later fermentation which takes place after the alcoholic fermentation is completed, and it appears to be produced in larger quantity at high temperatures than at low. We shall see immediately that fusel-oil and the other bye-products met with in spirits

¹ c.c. alcohol in 100 vols. $\times 0.8$ = grammes in 100 vols.

Grammes alcohol in 100 vols. $\times 1.25$ = c.c. in 100 vols.

" " in 1 litre $\times 7$ = grains per gallon (6 bottles).

have effects on the body in health and disease only second to that of the ethyl alcohol itself.

WHISKY.

Whisky has been defined by the Chairman of the Inland Revenue Board as 'a spirit made from malt or malt and grain, and distilled in pot-stills.'¹ In the United States Pharmacopœia it is described thus: 'A spirit obtained from fermented grain by distillation, and containing from 48 to 56 per cent. by volume of alcohol. It should be free from disagreeable odour, and not less than two years old.'

It is important to distinguish clearly between genuine 'malt whisky,' which is made in 'pot-stills,' and 'grain whisky,' which is prepared in 'patent stills.' The bulk of ordinary whisky as it reaches the consumer is probably a blend of these two, grain whisky usually predominating.

(a) **Malt whisky** is prepared from malted barley which is first carefully dried. In many Highland distilleries peat is used as the fuel for drying, and some of the characteristic flavour of such whisky is believed to be derived from the peat smoke. After being dried, the malt is made into a mash, and here, just as we shall see is true of beer, the nature of the water used seems to have some influence on the character of the final product, soft water giving the best result. The mash is then fermented much as in the making of beer, only the process is allowed to go on longer. When fermentation is complete, the fermented mash or 'wash' is distilled in the old-fashioned pot-still. This is the form of still which is by far the most commonly used in Scotch and Irish distilleries. It is made of copper, and the volatile products are condensed in a simple 'worm,' no attempt being made to separate the spirit from the bye-products. The still is heated over an open flame. This is a point of some importance, for it causes some of the sugary substances in the wash to become slightly charred, and there is produced in this way, amongst other things, the substance furfural, the presence of which is one of the chief distinguishing characteristics of pot-still whisky.

The first product of the distillation is called *low wines*. These are

¹ The Royal Commission on Whisky and Other Potable Spirits, which reported in 1909, however, concluded that the term 'Whisky' may legitimately be applied to the product of a patent still also.

redistilled, and yield (1) 'fore-shots,' (2) 'clean spirit,' or whisky, (3) 'feints'; the residue left in the still being the 'spent lees.'

The fore-shots and feints both contain much of the bye-products of fermentation, and are redistilled, the distillate being added to the clean spirit, or whisky.

It must be noted that no fusel-oil is obtained separately by this method of distillation, and the product consists of alcohol plus some of the bye-products of fermentation. The whisky thus produced has an alcoholic strength of from 13 degrees to 50 degrees over proof, but before bonding it is usually reduced in Scotland to 11 degrees and in Ireland to 25 degrees over proof.

The bye-products—chiefly aldehydes—which it contains give it, when young, a raw, harsh and disagreeable taste, but after keeping for some years in wood it mellows greatly, and the harsher the taste when young, the more full flavoured the whisky when matured.

What the exact nature of the changes is by which the improvement which whisky undergoes in wood is brought about we do not yet fully know. This we do know, however, that the percentage of alcohol diminishes, 6 to 8 per cent. of proof spirit being lost by five years' storage. On the other hand, the fusel-oil does *not* seem to undergo diminution, in spite of frequent statements to the contrary.¹

Irish pot-still whisky differs from Scotch in being prepared usually from a mixture of malted barley with unmalted grain (barley or maize), and the malt is not dried over peat. Otherwise the manufacture of the two is very similar.

(b) **Grain Whisky.**—This is the form of whisky most commonly distilled in England. It is made from a mixture of grains (barley, rye and maize), with just a sufficiency of malt to convert their starch into sugar. More important than this distinction, however, is the fact that it is distilled by steam and in a patent (Coffey's) still in such a way that the bye-products of fermentation (fusel-oil, etc.) are, to a large extent, separated from the ethyl alcohol. The result is that the raw product has much less flavour than young malt whisky, and is sooner ready to go into consumption. When run off the still it is almost colourless and has an alcoholic strength of 60 degrees over proof, but is usually diluted to 11 to 12 degrees over proof before bonding. It acquires a yellowish colour from being stored in old sherry-casks.

¹ See Dr. Bell's evidence before the Select Committee on British and Foreign Spirits, 1890-91. Allen, however, does not agree with this. He considers that some of the fusel-oil is converted into volatile ethers.

As regards the main differences between the two varieties of whisky, I would emphasize—

1. That patent-still whisky contains much less of the bye-products of fermentation (including fusel-oil) than pot-still whisky, and is therefore much purer.

2. That as a consequence of this patent-still whisky does not improve nearly so much on keeping as the other variety.

It follows from this that a young patent-still whisky is much better to drink than *young* malt whisky, but that the latter, when fully matured, has a fuller and pleasanter flavour than the former. It is absurd to object to grain whisky on the ground that it contains more fusel-oil than malt whisky, for just the reverse is the truth. After removal from bond, whisky is diluted—or ‘broken down,’ as it is termed in the trade—by the addition of water. The legal limit of dilution is 25 degrees under proof (42·7 per cent. alcohol by volume), and the majority of vendors may be trusted to take full advantage of the permission, so that the ordinary whisky sold in bottle is of this strength; indeed, of fifty-one samples of public-house whisky taken from all over the country, the strength was from 15 to 25 under proof in all but two instances.¹ In other words, we shall not go far wrong if we regard a glass of whisky as containing rather less than half a glass of absolute alcohol.

As already mentioned, most commercial whiskies are blends, and not the product of one distillery at all. Grain whisky is often used as the basis of the blend, a certain proportion of malt being added to give flavour. Even when the blend contains as much as 90 per cent. of grain whisky, it is often sold as ‘genuine malt.’² The public taste at present is certainly in favour of a mild-flavoured whisky, hence the large use of grain spirit in blends.

Pothēen is the product of illicit stills, and, being usually made from molasses, has the characteristics of rum rather than those of true whisky.

BRANDY.

If whisky be regarded as distilled beer, brandy may be spoken of as distilled wine.

¹ Select Committee's report. The limit of dilution is now 35 degrees under proof.

² There can be no question that such a practice is unfair to the consumer, for whatever may be said of the relative merits of malt and grain spirit, everyone has a right to know the nature of the whisky he is buying. It would be well, therefore, if the law should insist that the character and origin of the contained spirit should be printed upon the label of the bottle. (See ‘The Practice of Substitution in the Spirit Trade,’ *Lancet*, 1903, i. 542.)

The best brandy was originally produced in one of the richest wine districts of France (Département de la Charente or Cognac district). The quality varies with the character of the grapes, the best grapes yielding the variety known as Fine or Grande Champagne. This is the only genuine liqueur brandy. The varieties known as Petite Champagne and Première Bois rank next to it. If sold pure, these constitute old Cognac, but a large amount of them is used for blending with inferior varieties.

In a good year six or seven bottles of wine should yield one bottle of brandy. When first distilled the spirit is devoid of colour and of a fiery character. When kept in cask it takes up colour from the wood and gradually becomes mellow. Improvement goes on for a long time, so that the older the brandy the better. After twenty or forty years it contains a considerable proportion of volatile ethers and aldehydes, to which some of the most valuable properties of brandy are to be attributed.¹

While the above is the origin of genuine brandy, it must be admitted that very little of the brandy sold in this country is so derived. The greater part of it is really concocted in the Cognac district from 'silent spirit' coloured with burnt sugar and flavoured with œnanthine or various essences. Such a product is entirely different from genuine brandy, for it contains but little of those volatile ethers derived from wine which are so conspicuous in genuine Cognac, and to which, as we shall see, it owes most of the valuable results it is capable of producing in sickness.

The production of genuine brandy by the distillation of Spanish wines has recently been begun at Jerez and elsewhere, and the product is pronounced by competent authority to be fully equal, in regard to the amount of ethers present, to pure Cognac.² If this standard is maintained, Spanish brandy should have a great future. It is the possession of volatile ethers in large amount which mainly distinguishes brandy from whisky; as regards alcoholic strength, the two are about equal.

RUM.

Rum is usually produced by the distillation of fermented molasses obtained in the manufacture of raw sugar; the best varieties, how-

¹ For the changes which take place in brandy by age, see a paper by Rocques (ref. in *Analyst*, 1897, p. 38); also 'Report of the *Lancet* Special Analytical Commission on Brandy' (Supp. to the *Lancet*, 1902, ii. 1503).

² See 'The Composition of Brandy,' by Sir Charles Cameron and Professor W. R. Smith, *Journal of State Medicine*, 1899, vii. 317.

ever, are obtained by direct fermentation of the juice of the sugar-cane. The spirit contains bye-products of fermentation, which impart to rum its characteristic flavour. The chief of these is said to be ethyl butyrate, and a considerable proportion of the rum sold in this country is made from silent spirit flavoured with that substance.

Rum owes its dark colour to burnt sugar. When kept for some time, it improves greatly in flavour by the development of ethers in which it is peculiarly rich. It usually goes into consumption at about the same alcoholic strength as whisky, or perhaps a little stronger.

GIN.

Gin (also known as Geneva—from *genièvre*, a juniper—Schiedam and Hollands) is obtained by fermenting a mash of rye and malt, and distilling and redistilling the product. Juniper-berries and a little salt, and sometimes also hops, are added in the final distillation, and the product is run off into underground cisterns lined with white tiles, where the spirit can be kept without colouring.

The chief seat of the manufacture of genuine gin is at Schiedam in Holland. Much so-called gin, however, is fabricated elsewhere out of silent spirit flavoured with salt, juniper-berries, and turpentine.

Gin is allowed to be sold with as low a proportion of alcohol as 35 under proof (37 per cent. alcohol by volume), but is usually imported at 14 to 15 under proof. It is thus one of the most dilute of spirituous drinks. Sweetened and diluted gin is sold under the name of *Old Tom*.

Whilst varying somewhat in alcoholic strength, all the spirits we have been considering agree in containing very little solid matter—less, indeed, than 1 per cent., gin being the poorest in this respect. They have also a very low degree of acidity, rum standing highest, then brandy, with 1 grain per ounce (reckoned as tartaric acid), while whisky and gin have only about 0.2 grain per ounce. They are all practically free from sugar, for which reason the introduction of special whiskies for diabetics is quite unnecessary.

The following table, taken from the Report of the *Lancet* Special Analytical Commission on Brandy, represents the comparative composition of the different spirits in a convenient form :

Constituents.	Grain Spirit.	Beet Spirit.	Jamaica Rum.	Scotch Whisky.	Gin.	Typical 3-Star Brandy.
Alcohol per litre by weight	932.60	912.90	619.20	436.20	401.50	410.50
" " by volume	956.00	942.00	695.00	512.00	475.00	485.00
Equal to proof spirit per cent.	167.55	165.09	121.79	89.77	83.26	84.96
Extract per litre	Nil.	Nil.	6.36	1.16	0.52	6.70
Acidity (calculated as acetic acid)	2.40	4.80	122.40	33.60	19.20	37.50
Aldehydes (as ethylic aldehyde)	1.15	10.92	15.41	14.38	4.72	6.10
Furfural	Nil.	Nil.	2.08	1.94	0.13	0.82
Alcohol in ethers (not in total)	1.84	9.20	161.00	20.24	4.60	27.88
Ethers (expressed as ethyl acetate)	3.52	17.60	308.00	38.72	8.80	53.35
Higher alcohols	2.80	6.95	62.58	122.76	13.25	58.48

LIQUEURS AND BITTERS.

This group of liquors may be regarded as consisting essentially of spirit sweetened with cane-sugar and flavoured with aromatic or other herbs or essences. It has been well said that they are chiefly the product of the alchemist and the monastery. The proportion of alcohol in them is high, varying from 33 to 50 per cent. or more by volume. The proportion of the other ingredients is shown in the following analyses of some of the most prominent members of the group, taken from König :

	Alcohol.		Extract.	Cane-sugar.	Various Extractives.	Ash.
	By vol.	By weight.				
Absinthe	58.93	—	0.18	—	0.32	—
Benedictine	52.00	38.5	36.00	32.57	3.43	0.406
Crème de Menthe	48.00	36.5	28.28	27.63	0.65	0.043
Anisette	42.00	30.7	34.82	34.44	0.38	0.068
Curaçoa	55.00	42.5	28.60	28.50	0.10	0.040
Kümmel	33.90	24.8	32.02	31.18	0.84	0.058
Angostura	49.70	—	5.85	4.16	1.69	0.068
Chartreuse	43.18	—	36.11	34.37	1.76	—

The following is a brief description of the origin and constituents of some of the better-known liqueurs and bitters :¹

Absinthe.—Made by macerating Alpine plants of the wormwood species with the root of anise and sweet-flag and marjoram leaves in 40 per cent. spirit. A glassful (30 c.c.) contains the following amounts of absolute alcohol :

¹ For this description the author is largely indebted to Simmonds' 'Popular Beverages of Various Countries,' London, 1888.

Ordinary absinthe	..	14'3 c.c.	|	Fine	..	..	..	20'4 c.c.
Demi-fine	..	15'0 „	|	Suisse	..	..	..	24'2 „

The essential oil of wormwood is a convulsive poison.

Curaçoa.—Made in Amsterdam from the rind of bitter oranges grown in the island of Curaçoa.

Kirsch.—Made from cherries in the Black Forest.

Noyau.—Made from the stones of cherries, containing oil of bitter almonds.

Maraschino.—Made by fermenting a small sour cherry (*marasca*) grown in Italy and Dalmatia. Both the cherries and the stones are crushed and 10 per cent. of honey added, and the whole fermented. The spirit is diluted, and kept for some months to mature.

Kümmel.—Consists of brandy flavoured with cumin and coriander.

Vermouth.—Chiefly made in Turin from white wine flavoured and rendered bitter with Pontic wormwood and orange wine, and sweetened by the addition of 20 per cent. of sugar.

Chartreuse.—Originally made at the chief Carthusian monastery, near Grenoble, in France, and also at Florence. It contains a large proportion of sugar, the flavour being derived from various oils contained in angelica, hyssop, nutmeg, peppermint, and other herbs.

Benedictine is a very similar product, made at the Abbey of Fécamp.

Angostura is now chiefly made at Trinidad, but formerly at Angostura, the chief flavouring ingredient being the bark of that name, though other species are also added.

Ratafia is a name now applied in France to various liqueurs made from spirit, sugar, and aromatic herbs. It derived its name from the fact that it used to be drunk at the ratification of compacts and bargains.

The action of spirits on digestion is practically identical with that of pure alcohol. They can only delay digestion in virtue of the alcohol which they contain, and then only in intoxicating doses. In moderate quantity their influence is probably favourable rather than otherwise, just as is that of alcohol itself. Their acidity is so slight that they have but a small effect on salivary digestion.

Liqueurs taken at the end of a heavy meal may perhaps give a fillip to digestion, and counteract to some extent any retarding influence of coffee taken at the same time, but the large quantity of sugar which they contain makes them irritating to an empty stomach and possible causes of acidity.

In studying the general action of spirits on the body, one must

distinguish carefully between the action of the alcohol itself and that of the bye-products of fermentation which occur along with it. It would be a great mistake to regard spirits as simply mixtures of alcohol and water in nearly equal proportion.¹

Their high alcoholic strength renders all forms of spirits valuable stimulants where the action of alcohol pure and simple is desired. For such a purpose whisky is as good as any other, and pot-still or malt whisky possesses no real advantages other than flavour over the patent-still or grain spirit.

In cases of profound nervous and cardiac exhaustion, on the other hand, especially if delirium be present, one does not want merely an action upon the heart, but that stimulating influence upon the brain and vital centres which the volatile bye-products seem to be alone capable of exerting. Pot-still whisky, rum, and genuine brandy possess these bye-products, and especially those of an ethereal nature, in largest proportion, and therefore are much to be preferred in such a case. It is important, however, that these spirits should be old and well matured, for it is only then that they become really rich in ethereal bodies, and, of the three, genuine liqueur brandy is far the best.² In a case presenting signs of profound nervous and cardiac prostration the best liqueur brandy should alone be employed, no matter how much one has to pay for it. There can be no doubt that its free and timely administration has saved many lives.

‘It is when our patient is far beyond the region of controversy, and life itself is “in the balance,” that I find a sphere of marvellous usefulness for the best liqueur brandy, or, in lieu of it, very old cognac. Brandy, or even whisky, where the alcohol has been changed by age and original quality into vinous and ethereal spirit, is almost a pure stimulant, and hardly an intoxicant or narcotic at all. . . . Low forms of bronchitis and congestion of the lungs, the extreme exhaustion of some forms of influenza, the later stages of typhoid, cases of worn-out stomach from gastric catarrh, cases of breakdown from overwork, etc., all of them characterized by weakness of heart, failing circulation, inability to take food, loss of the power to sleep, and exhaustion, come into the category of suitable cases’ (Murray).

¹ It is only right to mention that the bulk of the medical evidence given before the Royal Commission on Whisky was in favour of the view that the results obtained from whisky in the treatment of disease are due essentially to the ethylic alcohol which it contains. See also Charteris and Cathcart (‘The Physiological Action of Whisky on the Circulation’), *Brit. Med. Journ.*, 1907, i. 1174.

² See Anstie, ‘On the Uses of Wines in Health and Disease,’ p. 44, and Murray, ‘Liqueur Brandy’ (‘Rough Notes on Remedies’), third edition, p. 135.

Spirituous liquors are too highly alcoholic for ordinary dietetic use unless taken in great moderation and freely diluted. Two or three glasses of whisky or brandy contain as much alcohol as most people can safely consume in one day. If this limit be observed, however, and the spirit freely diluted, they may agree well, owing to their almost complete freedom from sugar or acids.

It is of interest to inquire at this point what constitutes the difference between a good and a bad spirit. Why, for instance, does a crude whisky produce headache, furred tongue, and derangement of digestion, while a well-matured spirit has no such effects? and why does one produce sudden and almost maniacal intoxication while another does not? Much as this question has been discussed, it must be confessed that no satisfactory reply to it is yet forthcoming. One may wade through the evidence given by experts before the Commission on British and Foreign Spirits, or that on Whisky, and find nothing but confusion and contradictory statements.

The public have a general notion that the bad effects of immature spirits are due to the presence of fusel-oil. Let us inquire into this for a moment. We have seen that 'fusel-oil' is really a mixture of alcohols of higher boiling-point than ethyl alcohol. The exact nature of these alcohols varies with the source of the distillate. In brandy and patent-still whisky propyl alcohol is the chief one present; the fusel-oil of malt whisky and rum consists mostly of butylic and amyl alcohol. Now, experiments have certainly shown¹ that these higher alcohols have a much greater toxic action than ordinary ethyl alcohol. But even in a bad whisky there is not more than $\frac{1}{10}$ per cent. of fusel-oil present (about a grain to the glassful), and by experiment it is known that at least 1 per cent. is required to produce any marked effects. Further, the effects of fusel-oil have been put to direct tests in the human subject. King Chambers² says that he gave fusel-oil to various people in doses of from 1 to 10 drops, with the result of producing feverishness, furred tongue, throbbing of the temples, and headache; but other observers failed to get these results. Allen,³ for instance, swallowed for a month considerable quantities of whisky to which he had added as much as 2 per cent. of fusel-oil without experiencing any bad results. Mr. Samuel, F.C.S., stated before the Commission on Spirits that

¹ See Dujardin Beaumetz, 'L'Hygiène Alimentaire'; Richet's 'Dictionary of Physiology,' article 'Alcohol'; and Binz's 'Lectures on Pharmacology,' N.S., 1895, i. 347; also Baer, *Archiv. f. Anat. und Physiol.*, 1898 (*Phys. Abth.*), 283, and Jeffroy and Serveau, *Archives de Méd. Expér.*, 1897, ix. 681.

² 'Manual of Diet in Health and Disease,' p. 78.

³ *Journal of the Society of Chemical Industry*, April 30, 1891.

he had consumed 4 ounces of brandy a day for four days containing $\frac{6}{10}$ per cent. of fusel-oil, and found no bad effects from it. This quantity was equivalent to 24 ounces of ordinary brandy with $\frac{1}{10}$ per cent. of fusel-oil. Finally, Zuntz¹ has stated that when a controversy about fusel-oil was raging some years ago he gave patients considerable doses of it in capsule, and never observed any bad symptoms in the form of indigestion, headache, etc.

When we add to these results the fact that it is by no means clearly proved that old whisky is poorer in fusel-oil than young, it must be admitted that one can no longer regard the traces of higher alcohols in spirits as being responsible for the bad effects which these liquors sometimes produce. One is consequently confined to the supposition that the offending material is to be found amongst the other bye-products of fermentation, probably aldehydes such as Furfurol, while the local irritating effects of immature spirits on the stomach may be due to some empyreumatic body, *e.g.*, pyridine.²

As regards the greater intoxicating effect of crude spirits, it must be pointed out that these may be due to the quantity and not to the quality of the liquor consumed, for spirits lose a considerable proportion of alcohol when stored in wood. Binz has made the ingenious suggestion that some of the volatile ethers, produced in old spirits by oxidation, act as correctives to the action of alcohol, much as atrophine does to morphia, but of this there is as yet no experimental proof.

MALT LIQUORS.

This group includes beer or ale, and porter or stout. There is some confusion in the use of these names, and they have not quite the same meaning in all parts of the country. In some places the term 'ale' is applied to the brown beverages, while the black drinks are spoken of as 'beers.' It is better to regard the terms 'ale' and 'beer' as synonymous, and to apply them to the paler liquors, and to speak of the blacker drinks as stouts or porters. There is some reason, however, to believe that ale and beer were not originally identical, but that the former term was the earlier, 'beer' being only employed subsequent to the introduction of hops.

Beer may be defined as the product of the fermentation of malt and hops. We shall see later that much of the 'beer' in common use has not, strictly speaking, quite this origin.

¹ *Deut. Med. Wochens.*, 1893, xix. 466.

² For a full discussion of this subject see a paper ('Concerning Injurious Constituents in Whisky, and their Relation to Flavour'), by Lauder Brunton and Tunncliffe, *Lancet*, 1902. i. 1591.

Malt is obtained by moistening barley and allowing it to germinate in heaps at a moderate and regular temperature. During germination important changes take place: the ferment diastase appears in the grain and acts upon some of the starch, converting it into dextrin and malt-sugar, while part of the proteins, by the action of another ferment, is also converted into soluble forms. The 'green malt' so produced is next dried, and upon the exact temperature at which this is carried out the character of the beer largely depends, for the lower (within limits) the temperature employed, the more powerful is the action of the ferments contained in the grain, and the larger the amount of soluble substances produced. Low-dried malts produce pale beer; those dried at a higher temperature yield a darker product.

When drying is complete, the malt is ground and made into a mash with water. Rather hard waters yield, for some reason, the best beer, the water of Burton-on-Trent being apparently specially well suited for the purpose, and, indeed, in most breweries the water is artificially made up to the standard of that locality.

After mashing, the wort is strained off from the malt and boiled for an hour or two with hops. Boiling stops any further action of the diastase, and extracts from the hops their soluble ingredients. Chief amongst these are tannic acid and certain resinous bodies of bitter taste. A substance called 'hopein,' the nature of which has not been fully investigated, but which seems to have properties resembling those of morphia, is also extracted. 'Lupulin,' which is the secretion of the glands of the hop, does not seem to be present in the finest varieties. The boiled wort is next pumped out and rapidly passed over coolers, and is then ready for the addition of the yeast. Great care is now taken to employ pure yeast, for many of the diseases of beer, such as the development in it of acetic acid, are due to contamination with 'wild' yeasts. Scientific brewing has made great progress in this direction in recent years. The yeast is added to the wort in vats, and fermentation is then allowed to proceed. Here, again, much depends upon the temperature employed. In this country fermentation is usually conducted at rather high temperatures, with the result that most of the sugar is broken up and the resulting beer is rich in alcohol. In Germany low temperatures are employed, and more sugar and dextrin are left in the beer, but less alcohol is produced. Low-fermentation beers also contain more carbonic acid than most English beers, and are therefore better aerated. It is thus that lager-beer is produced.

When fermentation is complete, the yeast, which has been carried

to the surface, is skimmed off, and the beer is allowed to stand in shallow tanks till most of the remaining yeast has settled to the bottom. It is then run off into casks. Here a secondary fermentation occurs under the action of the small quantity of yeast still contained in the beer, but it is restrained to some extent by the addition to the cask of an extra quantity of hops. The longer this lasts, the greater is the amount of alcohol produced, and if strong beer is desired it must be left in the cask for some months. At the same time some volatile bodies seem to be developed which impart to such beer its full flavour, while the production of more carbonic acid under pressure leads to partial solution of that gas, and gives to the liquor a pleasant sharp taste. Just before bottling a solution of isinglass in acetic or tartaric acid ('finings') is added to the cask, which soon settles down in the form of a precipitate, carrying with it any remaining yeast cells and other impurities.

After bottling, the beer becomes brisker than it was in the cask, probably because no gas can now escape from it. Strong beer will keep well in bottle for eighteen months.

The taste for strong, full-flavoured ales seems now to be passing away, and a weaker and milder beverage is more largely produced, which, from the rapidity with which it goes into consumption, is termed 'running ale'; carbonic acid is often added to it by artificial aeration, and in order to insure its keeping an antiseptic is frequently added, especially in hot weather. Sulphite of calcium is largely employed for the purpose. It falls down quickly in the form of sulphate and does no harm. Salicylic acid is also used, but as not more than $\frac{1}{2}$ ounce is usually added to a 36-gallon cask, it may be regarded as quite innocuous. It is apt, however, to affect the flavour of the beer to some extent.

The names applied to different beers vary in different breweries, and many of the commercial brands are made by the judicious blending of beers produced in different ways. One can distinguish broadly between mild and bitter ales, the former containing relatively more malt and less hops than the latter, while in mild the malt is also dried at a higher temperature.

Indian Pale Ale is so called because it was first produced for the Indian market. It is very thoroughly fermented, and contains, therefore, but little sugar, and being highly hopped it has good keeping properties, for the hops act as an antiseptic.

In an ordinary public-house the varieties usually distinguished are 'four-ale' (i.e., 4d. per quart), which is the poorest; 'six-ale'

(6d. per quart), which is a mixture of mild and bitter and comes next; and after that 'bitter' and 'Burton,' the last being the strongest of all.

The description of brewing given above applies only to 'pure' beers—that is to say, to beverages brewed only from malt and hops. A very large proportion, however, of the beer in ordinary consumption has not this origin, some cheaper source of sugar than malt being employed. Amongst the substitutes so used are invert sugar, potato glucose, flaked maize and rice; and the liquor produced from them is sometimes termed *substitute beer*.

A large amount of evidence concerning the production of these beers and their effects upon health was given before a Parliamentary Commission a few years ago, but it must be admitted that the results were not very definite or satisfactory. It would appear that it takes an expert to tell the origin of a beer from its flavour, and it was certainly not clearly shown that the 'substitute' beers are really injurious to health, while they can undoubtedly be produced more cheaply than the genuine article.¹

Porter or stout is made in the same way as beer, but the malt is first roasted in cylinders, much as coffee is. This has the effect of producing some caramel, to which the dark colour of these beverages is mainly due, and it must also, by killing the diastase, prevent the further production of dextrin and sugar in mashing. The proportion of solid matter in the liquor is often enhanced by the artificial addition of caramel or of invert sugar.

German beers, as has been mentioned, are fermented at a lower temperature than those of this country, and contain more dextrines. Secondary fermentation takes place in them to a large extent, and produces much carbonic acid gas. They are decidedly less alcoholic, and more nourishing than English beers.

¹ Since the above was written an epidemic of arsenical poisoning has occurred from the consumption of 'substitute' beer prepared from impure glucose. Too much importance, however, must not be attached to such an accidental occurrence in deciding the question of the relative wholesomeness of 'pure' and 'substitute' beers. The statement still holds good that provided the materials used in its manufacture are free from impurity 'substitute' beer has not been shown to be injurious to health.

COMPOSITION OF MALT LIQUORS.

The most important constituents of these beverages are alcohol, dextrins, sugar, and a small amount of soluble nitrogenous matter (together these make up the 'extract'), and vegetable acids.

The following table¹ gives the approximate composition of some of these beverages:

	Water.	Alcohol. Per cent. by vol.	Total Extract.	Protein.	Sugar.	Dextrins.	Acidity as Lactic Acid.	Ash.
Bavarian winter beer	91·81	3·21	4·99	0·81	0·44	2·92	0·116	0·20
Bavarian summer beer	90·71	3·68	5·61	0·49	0·87	4·39	0·128	0·22
Munich Hofbräu ..	—	3·70	5·87	—	—	—	—	—
Spatenbräu ..	—	3·23	6·61	—	—	—	—	—
Pilsener	91·15	3·46	4·97	0·37	—	—	0·16	0·20
Munich Bockbier ..	88·72	4·07	7·23	0·71	0·90	—	0·17	0·27
English ale and porter	89·1	4·89	6·03	0·53	0·84	—	0·31	0·31
Berlin white beer ..	—	3·91	4·85	—	—	—	—	—
Allsopp's Lager ..	89·49	5·40	—	0·40	2·04	3·34	0·12	0·27

The following is an analysis of Burton pale ale by Chittenden and Mendel²:

Alcohol	4 to 5·25 per cent. by vol.
Extract	4·4
Ash	0·35

The composition of two good specimens of stout is thus given by the *Lancet*³:

	'Oat Stout.'	'Nourishing Stout.'
Extract	6·3 per cent.	8·0 per cent.
Alcohol by vol. ..	6·24	6·55
" by weight ..	5·0	5·25
Acidity	0·90	—
Ash	0·45	0·33

Chittenden and Mendel's analysis of Guinness's Dublin Stout is as follows:

Alcohol (by vol.)	5·5 per cent.
Extract	5·42
Ash	0·36

¹ From Leyden's 'Handbuch der Ernährungs Therapie,' i. 103.

² *American Journal of the Medical Sciences*, 1896, cxi. 177.

³ 1897, ii. 314; *ibid.*, 1898, i. 1408.

It has been calculated that the chief ingredients of a pint (20 ounces) of good average bottled beer are these :

Alcohol	..	..	..	1 fluid ounce.
Extract	..	..	..	1 to 2 ounces.
Free acids	..	..	..	25 grains.
Salts	..	..	..	13 „

ACTION AND USES OF MALT LIQUORS.

1. Action on Digestion.—Malt liquors have but little retarding influence on salivary digestion, and what action they do possess is entirely due to their acidity. Stout is twice as acid as beer, and hence has a greater retarding action on the digestion of starch by the saliva.¹ Sound beer, indeed, in some experiments,² seemed actually to increase rather than restrain the action of ptyalin, but sour beer has a decidedly retarding effect.³ On the other hand, in the living body the bitterness of beer may bring about a more profuse flow of saliva, and so end by improving rather than impairing salivary digestion.

In the stomach beer does not remain, if taken alone, any longer than water, for 200 c.c. are found to have completely left it in about one and a half hours. If taken with other food, it delays the chemical processes of digestion more than the mere amount of alcohol which it contains will explain. Some⁴ have blamed the 'extract' for this, others the salts;⁵ but the action is, in any case, not an important one, for even half a litre of beer (about a pint), when taken with a mixed meal, was found to produce but very little delay in the stomach.⁶ It is probable, indeed, that a tumblerful of good, brisk beer may actually aid digestion by increasing appetite and calling out a more abundant secretion of gastric juice and more active movements of the stomach.

Malt liquors seem sometimes to give rise to 'acidity' in the stomach. This may, perhaps, be the result of acid fermentation of the liquor, especially if it has not been kept very long in the cask.

Beer is found by some persons to have an unfavourable influence on the liver, producing a sort of dyspeptic sluggishness. The way in which it does this is not fully understood, nor whether it is to be attributed to the malt or some ingredient of the hops. It is for this reason, amongst others, that beer is not a good beverage for the

¹ Chittenden and Mendel, *op. cit.*

² Aitchison Robertson, *Journal of Anatomy and Physiology*, 1898, xxxii. 615.

³ Roberts, 'Digestion and Diet,' p. 119.

⁴ Simanowsky, *Arch. f. Hygiene*, 1886, iv. 1.

⁵ Buchner, *Deut. Archiv. f. Klin. Med.*, 1881, xxix. 537.

⁶ Buchner, *op. cit.*

sedentary unless in very moderate amount. Stout is popularly believed to be more 'digestible,' and perhaps rightly, but bottled stout is an admirable soporific. 'If it be desired to avoid nervousness,' says Hutchinson, 'and to get rid of insomnia, shun tea and coffee, and drink Guinness's stout. . . . I scarcely ever met with a man who could withstand the soporific effects of bottled stout. It is far better than opium, and induces a more nearly natural sleep.' It is interesting in this connection to note that the residue of dried beer is found to have a sedative influence very much like that of morphia; this has been ascribed to 'hopein,' one of the soluble constituents of hops.

2. **Influence as Foods.**—The large quantity of carbohydrate matter in malt liquors renders them the most truly nourishing of alcoholic drinks. A pint of good ale contains as much carbohydrate as $1\frac{1}{2}$ ounces of bread.

I found the following amount of solids in some common varieties:

	Grammes in 100 c.c.			
Pilsener Lager (Bremen)	2.7
Amsterdam Pilsener	4.1
Allsopp's Light Dinner Ale	5.2
Bulldog Stout	6.6
Bottled Lager (Bürgerbräu)	6.8
Nourishing Stout (Mountjoy Brewery)	9.2

According to these figures, an imperial pint of Allsopp contains 30 grammes of solid matter, and has in addition about 36 c.c. of alcohol. Together these will yield about 337 Calories of energy, and 2 pints will contain one-fifth of the total energy required daily. A glass of milk yields about 184 Calories, a similar glass of good bottled beer about 168. It does not follow from this, however, that beer is almost as good a source of energy as milk, for, as we have seen, alcohol is to be regarded as a food of only limited value. Five litres of good German beer with 5 per cent. of 'extract' should yield 250 grammes of carbohydrate (1,025 Calories), which is half the total required daily, and in addition 100 to 150 grammes of alcohol, with a fuel value of 700 to 1,050 Calories.

Malt liquors must be strictly forbidden in many forms of disease. The combined effects of their alcohol and carbohydrates render them specially prone to produce obesity, and they are also to be regarded as frequent predisposers to gout. In all cases of inflammation of the mucous membrane of the genito-urinary tract, also, they seem, for some reason, to have a peculiarly bad effect, and the recurrence of a gleet, for instance, can often be traced to their use. They are too rich in carbohydrates to be suitable for any but the mildest cases of

diabetes. Special beers are prepared, however, which contain very little extract and no sugar, and these can be safely recommended in cases of obesity or diabetes.

It must be remembered also that malt liquors are bulky drinks, and indulgence in them introduces a large amount of fluid into the circulation. The effort to expel this surplus fluid throws an extra strain on the heart, which may be very injurious if that organ is already damaged. In Bavaria a special form of hypertrophy of the heart ('beer-heart') is not uncommonly produced in this way, even in otherwise healthy persons.¹

¹ See Von Strümpell, 65ten Versamml. deut. Naturforscher und Ärzte zu Nürnberg, p. 97, 1893.

CHAPTER XXI

ALCOHOLIC BEVERAGES (*continued*): **WINES**¹

WINE may be defined as a beverage produced from the pure juice of the grape by fermentation. Some add to this definition the saving clause, 'or with such additions only as are believed to improve its durability.' The quality of the wine depends very much upon the variety of the grape, the soil upon which it is grown, the mode in which it is cultivated, and the climatic conditions of particular years. The juice is obtained by crushing the grapes, treading being the method usually employed in order to avoid squeezing the stalks and stones too much, and so extracting undesirable ingredients.

The chief **chemical constituents of the juice** are sugar, albuminous matters and certain acids, of which the most abundant are tartaric and tannic acids. The sugar is a mixture of grape-sugar, or dextrose, and fruit-sugar, or lævulose, in the proportion of about three parts of the former to one of the latter.

The relative amount of albuminous matter and sugar in the juice has much influence on the character of the wine produced. The yeast lives upon the albuminous matter, and splits up the sugar, with the formation of alcohol and other products. If there be but little sugar and much albuminous matter present, the yeast can go on growing until all the sugar is split up. The wine will then be 'dry' and of an acid taste. Such a wine is hock. If, on the other hand, the sugar is out of all proportion to the albuminous substances in

¹ In obtaining material for this chapter, the author has been much indebted to the following, among other, publications: Thudichum and Dupré, 'A Treatise on the Origin, Nature and Varieties of Wine,' London, 1872; Thudichum, 'A Treatise on Wines,' Bohn's Scientific Library, 1896: in the preface references will be found to most other modern works on the subject; Gautier, 'La Sophistication des Vins,' 1884; Mulder, 'On the Composition of Wines' (edited by Bence Jones), 1857; Dupré, 'What is Wine?' (*Popular Science Review*, 1868, vii. 354); Windisch, 'Die Chemische Untersuchung und Beurtheilung des Weines,' Berlin, 1896; Anstie, 'On the Uses of Wines in Health and Disease,' Macmillan and Co., London, 1877; 'In Vino Veritas' (edited by André L. Simon), Grant Richards, Ltd., London, 1913. References to other papers will be found in the text.

the juice, a limit is set to the growth of the yeast, and some sugar will be left in the wine, and it will then taste sweet. Should, however, the sugar and albuminous matter be present in more equal amount, the wine will retain some of both, and, though not sweet, will not have a distinctly acid flavour either, and will be of full 'body.' Such a wine is burgundy. It must be remembered, moreover, that no matter how much albuminous substance and sugar the juice may contain, the production of alcohol cannot go on indefinitely, for the accumulated alcohol ultimately ends by paralyzing the yeast. This takes place when the proportion of alcohol in the fermenting liquid has reached about 16 per cent. by volume. Hence it is that a 'natural' wine can never contain more alcohol than this; indeed, there is rarely so much sugar present in the juice as to allow of its containing so much.¹ If a wine contains more than 16 per cent. of alcohol by volume, one may be quite sure that spirit has been added to it artificially; that is to say, it has been 'fortified.' Sherry and port as sold in this country are always 'fortified' wines; claret and hock, on the other hand, are 'natural' wines.

The colour of red wines is due to a pigment contained in the skins of the grapes, which is turned red by the acids of the juice. As the skins are left in the vat in making such wines, the alcohol which is produced gradually dissolves out this pigment, and so the wine acquires its red or purple tint. The colour of the white or brown wines is mainly due to the oxidation of tannic acid in the cask.

The yeast which adheres to the skin of the grape, and which is responsible for the fermentation of wine, is different from the yeast which produces the fermentation of malt liquors or spirits. Further, we now know that the characteristic qualities of different wines are due, in some measure at least, to the fact that they are produced by different species of yeasts. Thus, the yeast concerned in producing hock is different from that which produces claret, and by growing a hock yeast on a claret 'must' one gets a wine which is, as it were, a cross between claret and hock, and has some of the distinctive characters of both. Bacteriology has in recent years come to the aid of the wine-producer, and by producing pure cultures of the different yeasts will shortly, no doubt, make wine production a much more scientific and certain process than it has hitherto been, and we may perhaps look forward in the future to tasting varieties

¹ In order to produce 16 per cent. of alcohol in the wine, there must be 34 per cent. of sugar in the juice, while the usual proportion of sugar in the juice of most grapes is only from 13 to 30 per cent. Since the above was written, however, some natural Australian wines have been found to contain as much as 19 per cent. of alcohol by volume (see *Lancet*, 1901, i. 802).

of wine hitherto quite unknown. I have already pointed out that the bacteriologist, by working on similar lines, has already done this for cheese.

The exact details of the process of fermenting grape-juice in order to produce wine from it vary considerably in different countries and localities, and little would be gained by attempting to describe them in detail. As a rule, the first fermentation lasts for from two to six weeks, depending largely upon temperature, and the wine is left upon the lees till the spring, when it is siphoned off for storage. Prior to being placed in the cask, it is 'racked' by the addition of isinglass or white of egg, much as beer is by 'finings,' in order to remove albuminous matters (which prevent the wine from keeping) and suspended impurities. When clear, it is again 'racked' off from the deposit, and stored in casks in the cellar.

In the cask many very important changes take place to the occurrence of which the ultimate character of the wine is largely due. For one thing, the alcoholic strength of the wine rises. This is due to the fact that the water of the wine soaks into the wood more than the alcohol does, and is lost by evaporation, so that the wine becomes more concentrated. As the water so lost is replaced by the addition of more wine, the increase in the proportion of alcohol is rendered all the greater. In the cask, too, a partial oxidation of the tannic acid takes place. This causes the white wines to become darker in colour, but has just the reverse effect upon the red wines; for the oxidized tannic acid unites with, and carries down, some of their pigment.

The small quantity of yeast which always finds its way into the cask produces a slow secondary fermentation of the wine, which often lasts for years. As a result of this, some of the remaining sugar is converted into alcohol, and in this way also the alcoholic strength of the wine is increased. As the proportion of alcohol rises, some of the ingredients of the wine, such as tannic acid and bitartrate of potash, become less soluble, and fall down in the form of a deposit. During this time also some of the alcohol is oxidized into acetic acid, and the formation of compound ethers takes place. The maximum quantity of these, however, is usually reached in about five years, for the presence of water prevents the formation of ethers continuing till all available acids are used up.

After bottling, the formation of ethers still goes on, possibly with the aid of micro-organisms, but the alcoholic strength of the wine does not increase. It is quite a mistake to suppose that wine which has been kept long in bottle is necessarily stronger than a younger

wine. The reverse is the truth ; for the alcohol seems actually to diminish after the wine has been bottled some years. It is also an error to suppose that wine goes on improving indefinitely. Like all other organic things, it is liable to decay by the slow processes of oxidation, and few wines really improve after thirty years ; many, indeed, such as clarets, are at their best long before this, and it is only a few of the stronger wines, such as sherry and madeira, which will stand keeping for fifty, or possibly even a hundred, years.

CONSTITUENTS OF WINE.

The following is a list of the principal constituents found in grape-juice, or ' must,' and in the wine produced from it (Dupré) :¹

' Must ' contains :	Wine contains :
Water. Grape-sugar } 10 to 30 per cent. Fruit " } Malic acid. Tartaric acid. Racemic acid. Albuminous substances. ' Vegetable mucus.' Essential oils. Extractives. Mineral substances. Tannic acid Colouring matters } from the skins and Fatty substances } kernels.	Water. Grape-sugar } 0 to 6 per cent. Fruit " } Ethylic alcohol, 5 to 22 per cent. Propylic " Butylic " Amylic " Other higher alcohols. Malic acid Tartaric acid } Racemic " } Succinic " } 0·3 to 0·8 per cent. Acetic " } Formic " } Propionic,, } Butyric " Ethers of foregoing alcohols and acids Glycerine. Aldehyde. Carbonic acid and ammonia. Trimethylamin. Oils produced by fermentation. Albuminous matter. ' Vegetable mucus.' Colouring matter. Tannic acid. Essential oils. Extractives. Mineral matters, 0·15 to 0·6 per cent.

It will be realized from this what a very complex fluid wine is. ' It is a profound mistake,' says Dujardin Beaumetz, ' to regard wine as a mere mixture of alcohol and water. It is a complete living entity, if I may so say, of which all the elements constitute an *ensemble* so complex and homogeneous that we cannot modify one or another without producing profound changes in the composition of the wine itself. . . . Wine has its youth, its maturity and its old

¹ ' What is Wine ?' (*Popular Science Review*, 1868, vii. 354).

age. Some vintages, such as burgundy, have a short life, and become prematurely old; others, like claret, have a much longer life, and are even sent on a voyage to hasten their maturity. Wines, too, have their diseases—diseases which usually result from imperfect manufacture and bad fermentation, leaving in them impure products.' The amounts of the chief solid constituents in 1 litre of wine are roughly these (Gautier¹):

Water	..	..	..	..	718 to 935	parts
Glycerine	..	..	..	..	4	10
Colouring matter	..	..	..	..	0.6	1.5
Tartrates	..	..	..	..	1	3.75
Total solids	..	..	..	..	14	90

Ordinary Rhine and French wines have about 2 per cent. of solids; port has about 5 per cent. It would serve no good purpose, however, to give an analysis of wines in detail, for, after all, the information which chemistry can give us about wines is of limited value. It can tell us, it is true, a good deal about those ingredients which have most influence upon health, but it cannot tell much about those volatile compounds to which the most highly-prized qualities of wine, such as flavour and bouquet, are due, and for which one chiefly pays in buying wine when, indeed, one is not merely paying for the label on the bottle.

I propose, therefore, to describe briefly the most important of the constituents which influence health, and afterwards to consider the chief characters of some of the commoner wines in detail.

1. *Alcohols*.—Wine contains several alcohols, ethyl alcohol, however, being by far the most abundant. Amyl, propyl, butyl, and other higher alcohols are present in traces, being derived chiefly from fatty substances contained in the skins and stones of the grapes. A hundred volumes of a natural wine may contain anything from 6 to 12 grammes of ethyl alcohol. If there be less than this, the wine tastes flat; if there be more, one may be almost quite certain that alcohol has been added artificially—*i.e.*, that the wine has been 'fortified.' The advantage of fortifying wine is that it enables it to keep better, subsequent fermentation being restrained, and the production of acetic acid prevented. It is often necessary in the case of wines produced in very warm countries, where fermentation cannot safely be allowed to go on to its full limits, owing to the danger of the growth of 'wild' yeasts and the production of acids. Fortified wines not unfrequently have as much as one-third of their volume of spirit added to them, and require to be kept for a long time in bottle,

¹ 'La Sophistication des Vins,' 1884.

in order to re-acquire a true vinous character. Partial sterilization of the wine by the process of 'pasteurization' is now often used to effect the same object as 'fortification.'

2. *Acids*.—The natural acids found in wine are tartaric, malic and tannic. Acetic, formic, succinic and other fatty acids are produced by fermentation along with carbonic acid.

Tartaric and tannic acids are the most important. The former occurs combined with potassium in the form of bitartrate of potash or argol. As the proportion of alcohol in the wine rises, the bitartrate becomes less soluble, and ultimately much of it falls out in the form of a crust of 'tartar.' Hence it is that wines become less acid on keeping. The form of tannic acid met with in wine is probably not identical with that of oak-bark. It is chiefly derived from the skins and stalks, and is therefore more abundant in red wines. It diminishes by oxidation on keeping, and in the mature wine is not present in any large amount; for even an astringent red wine has only about 2 grains in a 2-ounce glass, while an ordinary glass of claret (4 ounces) has not more than 1 to $2\frac{1}{2}$ grains, or about as much as is contained in a cup of tea.

Acetic acid may be produced in wine by the growth in the 'must' of a special organism (the *Mycoderma aceti*), which, if unchecked, would ultimately convert all the wine into vinegar. It flourishes especially in very warm countries, and the necessity for preventing its growth is one of the reasons why the wines of such countries are so often fortified.

Acetic acid can also be produced by direct oxidation of the alcohol of wine in the presence of albuminous matter, and this occurs to some extent in the cask, and also in bottle, if any air finds its way into the wine through the pores of the cork. In order to prevent this, the bottle should always be laid on its side, so that the cork is kept soaked in wine.

In a sound wine the **total acidity** is not more than 0.3 to 0.7 per cent.; above this limit the wine will taste sour. It must be noted, however, that mere taste is no true indication of the acidity of a wine, for the sourness is much concealed by the presence of sugar. As a matter of fact, many sweet wines are quite as acid as the so-called sour wines.

Dupré found the following amount of acid (reckoned as tartaric) in one bottle of wine:

Claret	..	..	..	..	..	65 to 77 grains
Hock	..	..	..	..	..	57 „ 70 „
Sherry	..	..	..	..	..	54 „ 61 „
Port	..	..	..	..	..	49 „ 62 „
Marsala	..	..	..	..	..	39 „ 46 „

A sample of '47 port analyzed by Luff¹ had an acidity of 0.6 per cent., equivalent to 6 grains of tartaric acid in every wineglassful. He calculates that three-fourths of the total acid in two bottles of such wine would require to enter the circulation at one time in order to neutralize the alkalinity of the blood.

The volatile acids in wine (acetic, etc.) should not be present in a higher ratio than 1 to 3 of fixed acids (tartaric). If the proportion is higher than this, the wine is slightly 'turned'—*i.e.*, is on its way to become vinegar. Red wines usually contain rather more volatile acid than white.

3. *Sugar*.—The chief sugar found in wine is fruit-sugar, or lævulose. A 'natural' or fully-fermented wine should contain about $\frac{1}{2}$ per cent. of sugar; if there is less than this the flavour is not pleasant. As a rule, therefore, natural wines are 'dry.' Sauterne is one of the few natural wines which is rather rich in sugar. 'Fortified' wines in which fermentation has been checked by the addition of spirit contain 2 per cent. of sugar or more, while the sweet wines may have as much as 20 per cent.

Dupré found the following amount of sugar in different samples of wine :

Hocks	1.4 to 8.6 grains per bottle.
Clarets	11 .. 18 " "
Sherries	217 .. 421 " "
Ports	121 .. 519 " "
Old marsala ..	388 .. 451 " "
Sauterne	125 " "
Champagne ..	500 " " down to almost none.

It will be evident from this that sugar can hardly ever be present in wine to a sufficient extent to be of influence as a *food*. Even a sweet wine with 4 per cent. of sugar will contain only about an ounce in a bottle, or pretty much the same quantity as a bottle of ordinary lemonade. As Anstie points out, it is hardly possible to take in more than $\frac{1}{8}$ to $\frac{1}{2}$ ounce of sugar daily in the form of wine without at the same time consuming so much alcohol as would produce intoxication.

4. *Ethers*.—These are produced by the interaction of the alcohols and acids contained in the wine. They are very numerous as regards variety, as can readily be imagined when it is pointed out that a wine containing five different kinds of alcohol and five acids may contain twenty-five ethers. Their actual amount, however, is always very small. The highest proportion Dupré found was in a fifty-year-old madeira, and even then there was only 1 part of ether in every 300 of wine.

¹ 'Gout: its Pathology and Treatment,' Cassell and Co., 1898, p. 14.

The ethers of wine may be divided into two classes: (1) volatile, (2) fixed. The former are produced by volatile acids, such as acetic; the latter by the fixed acids, such as tartaric. The volatile ethers predominate in natural wines, while most fortified wines contain the fixed ethers in greater abundance. To this rule, however, sherry and madeira seem to be exceptions, for they are often rich in the volatile class.

Acetic ether is usually the most abundant volatile ether met with in wine, but old wines may contain traces of aceto-propylic, aceto-butylic, aceto-amylic, aceto-caproic, and aceto-caprylic ether as well.

The ethers—and especially the volatile ones—are of importance as imparting to wine much of its ‘bouquet,’ and a rough estimate of their richness in any particular wine can be made by noting the distance at which the bouquet can be smelt. They also contribute in large measure to some of the most important therapeutic properties of wine, as will be explained later.

The substance *œnanthine*, or *œnanthic ether*, demands special mention. It is derived from a hypothetical fatty acid (*œnanthic acid*) contained in the stones, stalks, and skins of the grapes, and more especially, perhaps, in the waxy fat which gives to the grapes their bloom. This acid is not found by itself in wine, but only in the combined or ethereal form. There is not more than 1 part of it in every 40,000 of wine, but along with glycerine and succinic acid it is mainly responsible for the peculiar ‘vinous’ smell and taste characteristic of all wines in common.

5. *Extractives* usually make up the bulk of the solid matter in all wines, except such as are rich in sugar. They consist chiefly of carbohydrates, such as pectins and gums. They contribute to the taste and ‘body’ of the wine.

6. *Glycerine* is produced along with alcohol in the process of fermentation, and is always present in wine and in sufficient amount to affect the taste. It is usually said that it amounts to one-fourteenth of the volume of the alcohol; but that is not quite accurate, for different yeasts seem to produce it in varying amount, so that no definite ratio between glycerine and alcohol can be laid down.

VARIETIES OF WINE.

Perhaps the most important division of wines is into (1) natural and (2) fortified. The **natural wines**, as already explained, are those in which fermentation has been allowed to go to its full limit—that

is to say, until the process is arrested spontaneously either by exhaustion of all the sugar and albuminous matter in the grape-juice, or until sufficient alcohol has been produced to prevent the further growth of the yeast. The latter consummation is reached when the fermenting juice contains 12 per cent. of absolute alcohol *by weight*, and natural wines, as defined by law, must contain less than that amount. Fortified wines, on the other hand, are those in which the process of fermentation has been artificially arrested by the addition of alcohol¹ either as 'silent' spirit, brandy, or some other concentrated form. Fermentation being thus arrested before all the sugar has been broken up, such wines are apt to be sweet, and are, of course, of comparatively high alcoholic strength.

Natural wines, on the contrary, are usually poor both in alcohol and sugar. The natural wines also, containing as they do a little acetic acid produced by prolonged fermentation, are rich in volatile ethers even in their youth, while the fortified wines, though they may ultimately contain much ether, only arrive at such richness in their old age, and the fixed ethers, except in the case of sherry and madeira, preponderate over the volatile. The distinction between natural and fortified wines is of further importance for this reason, that, as we shall see later, the natural wines are alone suited for habitual consumption as articles of diet, the fortified wines being rather to be regarded as medicinal agents.

The principal natural wines are claret and hock, and the Hungarian, Italian, Australian, and Californian wines. The chief members of the 'fortified' group are port, sherry, madeira, and marsala. Champagne and the Greek wines are also usually fortified.

Claret (probably derived from *clairret*, a thin *vin ordinaire*) is produced in the district of Médoc, the seaport of which is Bordeaux. It is a pure natural wine containing 8 to 13 per cent. of alcohol by volume, very little sugar (about $\frac{1}{4}$ per cent.), and a moderate amount of acids, acetic acid being always present to some extent. It contains also a high proportion of volatile ethers. The best growths, or 'crus,' are Château Margaux, Lafitte, and Latour.

Haut Brion is a red wine produced in the neighbouring district of the Gironde, and resembles a burgundy rather than a médoc. Sauternes are white wines made in the same district, and usually contain a good deal of sugar, from the grapes being allowed to hang for a long time on the vines before they are picked. The famous

¹ In the case of some fortified wines, however, *e.g.*, sherry, the alcohol is added after fermentation is complete.

Château Yquem is the finest of all the white wines so produced. Thudichum states that brandy is sometimes added to the natural wines of Bordeaux: not that it is required for their preservation, but simply in order to suit the English palate.

Burgundy resembles claret, but is richer in extractive matter, and has therefore more 'body.' It is also of higher alcoholic strength. It is produced in the district of that name, the best part being that which stretches between Dijon and Chalon. The most esteemed varieties are Beaune and Chambertin. Beaujolais and Mâcon, though not really produced in Burgundy, are usually classed with those wines. Ordinary burgundy is made from black grapes, but Chablis is a white burgundy produced from white grapes grown in the same district.

Hocks derive their name from Hochheimer, on the right bank of the Maine. With the exception of that produced at Assmannshausen, they are all pale wines. They have about the same alcoholic strength as claret, and contain hardly any sugar, for which reason they are apt to seem rather acid. Their acidity, however, is not much higher than that of claret (about $\frac{1}{2}$ per cent.), and they contain almost no acetic acid. They have the advantage of possessing a fine bouquet and extraordinary keeping qualities. The choicest varieties are those of Johannisberg, Steinberg, Marcobrun, Rüdesheimer, Rothenberg, and Hochheimer.

Hungarian wines are both red and white, and rank with claret and hock as the finest natural wines the world produces. Their alcoholic strength is about the same as that of the other two, but they are rather more acid. They resemble hock in being almost free from sugar. The finest variety, Tokay, is produced from grapes which have been allowed to dry on the stalks before being picked. It is a sweet wine of low alcoholic strength, and should have been kept very long in bottle. The special *Imperial Tokay* is one of the choicest wines known, but is never sold in trade. Some of the commoner dry Hungarian wines, both red and white, make excellent table beverages. They have rather more body than the corresponding wines of France, and a moderate degree of astringency.

Italian wines, both white and red, all belong to the 'natural' class. As a rule, they are of low alcoholic strength, but rather more acid and astringent than a light Bordeaux wine. Their acidity is rather high. The following analyses from the *Lancet*¹ represent the composition of some of the varieties more commonly sold in this country:

¹ 1899, i. 241.

	Capri (White).	Falerno (White).	Chianti (Red).	Barolo (Red).	Egidio Vitali (Sparkling White).	Valtellina (Red).
Alcohol by weight	11.62	8.64	9.36	10.85	10.08	9.36
" " volume	14.37	10.73	11.61	13.43	12.49	11.61
Tartaric acid ..	0.52	0.66	0.60	0.45	0.79	0.41
Acetic " ..	0.31	0.13	0.18	0.25	0.26	0.29
Sugar	0.76	0.11	0.17	0.18	3.67	0.13

Californian wines, from a merely chemical point of view, compare very favourably with the corresponding wines of Europe, though they are undoubtedly not yet equal to the latter in the more æsthetic qualities. For natural wines, they contain rather a high proportion of alcohol, but relatively little glycerine. In the white varieties the extract, total acidity and ash are generally lower than in the corresponding European wines, while in the red sorts these ingredients are relatively higher than in the old-world wines. A careful investigation of them has been made by Krug,¹ who concludes as follows: 'On the whole, it is evident that the Californian dry wines are fully equal to the European wines, and the red wines are in every respect superior to the young French clarets. The sweet wines are to be unconditionally preferred to the European Southern wines, containing the same amount of alcohol and extract, and not being plastered.' Their chemical equality with European wines is also confirmed by the *Lancet*,² from which the following analyses are taken :

			<i>A Californian Sauterne. Per cent.</i>	<i>A Californian Hock. Per cent.</i>
Alcohol by weight	..	..	10.31	10.00
" " volume	..	..	12.77	12.40
Extract .. ..	..	..	2.31	1.90
Ash .. ..	..	..	0.16	0.20
Total acids	..	..	0.69	0.67

The **Australian wines** resemble rather closely those of California, They are full-bodied natural wines, containing rather more alcohol than most clarets. They are chemically pure, and in recent years have improved very much in the finer characteristics of good wine, as the result of greater care in the cultivation of the grape.

The term **sherry** is applied to all the white wines of Spain, being derived from the town of Jerez, which may be regarded as the capital of the sherry-producing district. As drunk in this country, they are all fortified wines, containing from 15 to 22 per cent. of alcohol by weight. A 'natural' sherry is quite a possible product, but is never imported into this country on account of its being

¹ *Journ. of Amer. Chem. Soc.*, 1894, xvi. 597.

² 1894, ii. 30.

deficient in 'keeping' qualities. Sherries are also all 'plastered' wines; that is to say, sulphate of lime is sprinkled on the grapes after they are first trodden, in the proportion usually of $2\frac{1}{2}$ pounds to every ton.

The practice of **plastering** is one of great antiquity, and was mentioned long ago by Pliny. It was first adopted, no doubt, empirically, and the advantages of it are still far from being fully understood, although all experienced sherry-growers are of opinion that without its aid the production of a wine having the special characteristics of sherry is impossible. It may be that it acts as a preservative against the 'viscosity fungus,' which is so much commoner in Southern than Northern wines (Thudichum).

The chief chemical effect of plastering is to decompose the bi-tartrate of potash in the 'must' with the production of insoluble tartrate of lime, sulphate of potash, and tartaric acid, according to the following equation :



The phosphates are also thrown down.

As the tartrate of calcium falls out, it clarifies the wine, carrying down with it albuminous matters and suspended impurities. The tartaric acid produced renders the wine redder, and increases its free acidity, so facilitating the production of ethers later on.

There is introduced into the wine as the result of plastering 0.3 gramme of sulphate of calcium per litre, and 1.2 grammes of sulphate of potash, much of it, probably, in the acid form. The sulphate of potash may cause sherry to be slightly laxative to some persons if freely drunk, and renders it also somewhat bitter, but it cannot be said to have any other bad effects. It has been said that it may be productive of cirrhosis, but of this there is no sufficient evidence, and, indeed, the employés in the Spanish bodegas are stated to drink as much as $10\frac{1}{2}$ pints of light sherry daily, without suffering from any injurious effects.

The amount of sugar in sherry varies from practically nil in the driest sorts up to 4 per cent. in a very raisiny wine. The acidity is lower than that of the natural wines already considered.

Sherry develops in its old age a very large proportion of volatile ethers—more, probably, than any other alcoholic liquor, except a genuine cognac. To this property much of its value as a stimulant in disease is to be attributed.

Broadly speaking, there are two classes of sherries :

1. 'Fino,' a light, pale, delicate wine of Amontillado¹ or Manzanilla² type.

2. 'Oloroso,' a sweeter, full-bodied, brown wine. Intermediate between these is the class known as 'Palo Cortado.'

The following is an analysis of examples of these :³

			<i>Amontillado.</i>	<i>Oloroso.</i>	<i>Medium.</i>
			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Solids	..	..	2.20	5.45	2.87
Sugar	..	..	0.215	1.03	0.65
Potassium bitartrate	..	..	0.08	0.26	0.13
Tartaric acid	..	..	0.34	0.52	0.41
Acetic	"	..	0.12	0.20	0.10
Ash	..	..	0.55	0.86	0.70
Sulphate of potash	..	..	0.52	0.76	0.65
Alcohol by weight	..	..	14.82	18.85	15.67
" " volume	..	..	18.25	23.10	19.28
Total ethers	..	..	0.06	0.21	0.075

Pure sherry may be regarded as a genuine grape product, for the substances added to it in manufacture are also derived from grapes. Thus, 'grape liquor' is used for sweetening, and the same, slightly caramelized, for colouring. The spirit added in fortification is also obtained by distilling fermented grape-juice.

Port is the wine produced in the district of the Upper Douro, and takes its name from the town of Oporto. The whole of the wine that reaches this country is fortified, containing from 15 to 20 per cent. of alcohol by weight. One of the chief peculiarities of port is the large amount of 'extract' it contains, which gives it a full body. Its acidity is not great, less, indeed, than that of hock, but it contains relatively more acetic than tartaric acid, for the latter is insoluble in the large amount of alcohol which port holds. It possesses a good deal of tannic acid, the stalks not being removed before fermentation, but this diminishes with age, though when young it is very rough and astringent. It is sweeter than sherry, containing from 2 to 6 per cent. of sugar, for it is fortified before fermentation is complete, not after it, as sherry is. Old port contains a large proportion of ethers, but, unlike sherry, the fixed ethers predominate over the volatile. When mellowed it has an excellent flavour and bouquet, and retains only a moderate amount of fruitiness.

Madeira is derived from the island of that name. For a long time the ravages of the phylloxera stopped the production of the wine, but in recent years the industry has begun to revive. The wine resembles sherry in its general characteristics and in the high pro-

¹ Amontillado = à la Mantilla (a town near Cordova).

² From Manzanilla, a town near Jerez.

³ *Lancet*, 1898, ii. 1135 (Report of Commission on Sherry, from which many of the statements in the above paragraphs are taken).

portion of volatile ethers which it contains. It is a fortified wine, containing from 17 to 20 per cent. of alcohol by weight. *

Marsala is a Sicilian wine also resembling sherry, but sweeter and containing a much lower proportion of volatile ethers. It is only slightly acid.

Greek wines may be either natural or fortified, but usually contain only 8 to 14 per cent. of alcohol by weight. They are rich in volatile acids, and are peculiar, also, in containing some aldehyde. They are often plastered. Their chief defects are due to imperfections in the methods of manufacture.

Champagne is the wine produced in the Champagne district of France, the best varieties being obtained from the prefectures of Rheims and Epernay. It is produced, curiously enough, chiefly from black grapes. These are squeezed in a very powerful press, and the first pressings used to produce the finest wines. The character of the vintage in different years has also a very marked effect on the quality. The expressed juice, or 'must,' is allowed to stand for twelve hours in order to let all suspended matters fall out, and is then drawn off into casks to undergo the first fermentation. At this stage the different growths, or 'crus,' are blended to form the special 'cuvées,' the finest of which are only produced from the best grapes. The young wine is then bottled and left for two years, to undergo the secondary fermentation. The maintenance of a constant temperature is very important at this stage, and is attained at Châlons, Epernay, and Rheims, by storing the bottles in large cellars excavated from chalk cliffs. During this fermentation a large amount of carbonic acid gas is produced, and as the percentage of alcohol rises a considerable deposit falls down into the neck of the inclined bottle. This is fixed to the cork by freezing, and removed with the latter in the process of 'dégorgement.' The wine is still of a sour, harsh, or 'brut' character, and is made drinkable by 'dosage.' This consists in adding to it a solution of cane-sugar¹ dissolved in old champagne and good cognac. Upon the amount of dosage the sweetness or dryness of the wine depends. In this country we like champagne dry, and therefore only 2 to 4 per cent. of liqueur is added to the wine exported to England. For Russia, where a sweet wine is preferred, as much as 14, or even 16, per cent. of liqueur is used. The wines exported to the United States, Belgium and Germany receive an intermediate degree of treatment. There can be no doubt that the taste for a dry champagne is rewarded by

¹ The cane-sugar is gradually changed into invert sugar after its addition to the wine.

getting a purer wine, for heavy liqueuring covers many defects. Hence the dry wines are really the finest. It must be remembered, however, that unless 8 per cent. of liqueur has been added the quality of the wine will not be found to improve after longer than twenty years.

Champagne should, strictly speaking, be a natural wine, containing from 9 to 12 per cent. of alcohol by weight, but in recent years a taste for a stronger wine has grown up, and champagne as drunk in England is now mostly a brandied liquid (*Thudichum*). The amount of sugar varies from nil up to 14 per cent., depending on the dosage. The acidity is about 0.5 to 0.6 per cent.—*i.e.*, that of an average claret. A *dry* champagne contains about 2 per cent. of solid matter. A bottle of good champagne will contain about five volumes of carbonic acid gas. Four-fifths of this, however, is given off as soon as the cork is drawn.

The following table from Dupré's analyses may be of use for the purpose of comparing the chemical composition of some of the wines just described. It must be remembered, however, that mere chemical analysis is only of limited use in judging of the quality of a wine :

Wine.	Grammes Absolute Alcohol.	Free Fixed Acid.	Free Volatile Acid.	Total Acid.	Sugar.	Dry Resi- due.	Ash.	Total Alcohol in Ethers.
Hock (three samples) ..	9.73	0.399	0.088	0.506	0.062	1.92	0.17	0.042
Claret (three samples) ..	9.68	0.390	0.167	0.599	0.243	2.124	0.21	0.038
Hungarian wine (three samples) ..	10.16	0.454	0.192	0.694	0.077	1.906	0.18	0.046
Greek wine (three samples)	12.35	0.342	0.215	0.611	0.225	2.507	0.30	0.048
Sherry (three samples) ..	17.80	0.286	0.161	0.487	3.015	5.06	0.50	0.061
Madeira (two samples) ..	17.82	0.373	0.247	0.680	1.85	4.44	0.37	0.096
Port (three samples) ..	18.11	0.309	0.09	0.434	2.54	5.34	0.23	0.053
Marsala (two samples) ..	16.8	0.206	0.12	0.361	3.50	5.36	0.26	0.049

The table gives weights of different ingredients in 100 c.c. To get grains per bottle multiply by 120.

The following more recent analyses¹ may also be given :

THE COMPARATIVE COMPOSITION OF DIFFERENT VARIETIES OF WINE.

Wine.					Alcohol.	Extract.	Acid.	Sugar.
					Volume Per Cent.	Grammes per Litre.	Grammes per Litre.	Grammes per Litre.
A. French Clavets :								
Ch. Margaux	..	..	..	..	12'68	25'35	2'92	—
Ch. Haute Lafite	..	..	..	..	12'48	27'10	3'28	—
Bordeaux	..	..	..	..	10'70	27'24	3'48	—
Médoc	..	..	..	..	10'25	23'39	3'16	—
Ch. Margaux	..	..	..	..	11'60	29'99	3'30	—
Ch. Larose	..	..	..	..	10'01	24'09	3'28	1'08
Ch. Brane-Cantenac	..	..	..	..	11'68	23'44	3'02	—
Ch. d'Issan	..	..	..	..	9'91	20'80	2'76	0'92
Sweet Sauternes	..	..	..	..	11'68	36'12	3'97	14'0
Dry Sauternes	..	..	..	..	12'78	29'87	4'06	3'0
Haut Graves	..	..	..	..	12'00	28'34	4'56	2'7
Graves	..	..	..	..	12'27	34'16	4'99	4'0
B. Moselles :								
Moselle (1)	..	..	..	..	9'91	20'07	4'25	—
Schwarzberger	..	..	..	..	11'14	21'60	4'07	—
Moselle A.	..	..	..	..	10'66	20'26	4'23	—
Moselle '93	..	..	..	..	11'41	22'28	4'51	—
Moselle W.	..	..	..	..	9'23	18'31	3'63	1'35
Brauneberger	..	..	..	..	11'67	20'99	3'63	1'51
C. Hocks :								
Hock 1	..	..	..	..	11'41	19'06	2'98	—
.. 2	..	..	..	..	9'23	25'84	3'49	—
.. 3	..	..	..	..	9'74	23'52	2'80	—
.. 4	..	..	..	..	10'89	59'77	6'30	30'00
.. 5	..	..	..	..	9'76	22'36	4'02	1'51
D. Champagnes :								
Champagne, 1	..	..	..	..	13'70	35'70	4'02	19'2
.. 2	..	..	..	..	13'90	35'11	4'21	18'4
.. 3	..	..	..	..	13'48	35'20	4'12	15'6
.. 4	..	..	..	..	10'61	71'16	4'96	55'0
E. Australian :								
Australian, 1	..	..	..	..	14'20	29'65	2'96	—
.. 2	..	..	..	..	16'19	36'68	2'98	2'84
.. 3	..	..	..	..	13'39	29'15	4'05	1'08
.. 4	..	..	..	..	13'16	25'04	3'30	0'92
.. 5	..	..	..	..	14'48	37'40	4'17	2'57
.. 6	..	..	..	..	13'25	28'46	3'97	1'63
.. 7	..	..	..	..	15'46	88'27	4'21	50'00
.. 8	..	..	..	..	15'36	30'24	4'02	2'57
F. Spanish, 1	..	..	..	..	13'60	33'66	3'63	8'08
G. Italian, 1	..	..	..	..	10'79	22'90	3'63	1'00

Cider and Perry, derived from the apple and pear respectively, may be conveniently considered here, for they are really to be

¹ Report of the Hospital's Commission on Light Wines (*The Hospital*, 1907, xlii. 285).

regarded as wines; cider, indeed, when first made in England in the thirteenth century was always called 'wine.'

The finest English *cider* is made in Devon, Hereford and Somerset. The mid-season fruit, which ripens in October, is best for the purpose. It is gathered and allowed to mellow under cover for a fortnight, and is then ground to a pulp, the kernels being sometimes left out. The pulp is left in vats for thirty hours, and is then pressed, and 100 gallons of the liquor run into a clean vat and left for some days till it clears. It is then racked, clarified with charcoal and strained through bags, and the clear, bright liquid run into 100-gallon casks and bunged down.¹ Perry is made in a very similar way. If a 'sparkling' beverage is desired, fermentation is allowed to go on in bottle. The composition of these beverages seems to vary within rather wide limits. They are only mildly alcoholic, having 3 to 8 per cent. by volume, or much the same proportion as beer. Sugar amounts to 0.2 to 0.6 per cent. They are moderately acid (0.1 to 0.6 per cent.), the chief acid present being malic. The more acid varieties (0.6 per cent.) will have an acidity equal to about 22 grains of tartaric acid per tumblerful.

A sample of genuine Devonshire home-made cider which I examined had the following composition :

Alcohol (by volume)	..	..	..	6.0	per cent.
Solids	..	..	..	1.5	"
Total acidity	..	..	..	0.66	"
Volatile acidity	..	..	..	0.089	"

The following analyses are from the *Lancet* :²

				<i>Cider.</i>	<i>Champagne Perry.</i>
Alcohol by weight	..	..	..	2.70	1.45
" " volume	..	..	..	3.40	1.80
Solids	..	..	..	8.16	11.0
Ash	..	..	..	0.32	0.35

French and American imported ciders are thinner and weaker than the home-made article. Bottled cider has less alcohol (3 to 4 per cent.) and more sugar (2½ to 6 per cent.) than draught.³

Medicated wines are concoctions, the basis of which is port or sherry, to which has been added extract of beef, extract of malt, peptone, pepsin, coca leaves, cocaine, cinchona, iron, or some other dietetic or medicinal substance. A 'beef and malt wine' may usually be regarded as containing about 1½ ounces of extract of meat

¹ Radcliffe Cooke, *Journ. of the Soc. of Arts*, 1895, xliii. 396.

² October 1, 1892.

³ Felix Aury, 'Le Cidre et le Poiré,' Thèse de Paris, 1894.

and 2 ounces of malt extract in a pint of 'detannated' port or sherry.¹ For the medicinal wines there is no definite formula. Of the 'coca' wines, some are made from coca leaves, others from liquid extract of coca, and some from hydrochlorate of cocaine.

The following table² shows the proportions of the chief ingredients present in some of these wines, the composition of the ordinary standard wines being given for comparison :

Wine.	Alcohol by Volume.	Sugar by Weight.	Meat Extract by Weight, corresponding to Nitrogen Found.	Pure Alcohol in a Wine-glassful.
	Per Cent.	Per Cent.	Per Cent.	Fluid Drachms.
Claret	9	0·25	—	1½
Hock	10	Trace	—	1½
Champagne (dry) ..	10 to 15	Trace to 2	—	1½ to 2
Sherry (dry)	18	0·2	—	3 to 3½
„ (brown)	23	1·0	—	3 to 3½
Port	20	2 to 6	—	3½
Bovril Wine	20·15	10·2	0·5	3½
Lemco Wine	17·26	12·8	0·6	2½
Wincarnis	19·6	18·2	1·2	3
Glendenning's	20·8	10·6	0·4	3½
Bendle's Meat Port Nutrient ³	20·3	8·0	2·5	3½
Bivo	19·2	11·5	3·4	3
Vin Regno	16·05	7·4	0·3	2½

The use of these wines can on no grounds be recommended. In the first place, they are not worth the price charged for them, for it is far cheaper and also better for an invalid to get beef or malt extract separately and take along with them, if need be, a definite quantity of sound wine of known antecedents.⁴ In the second place, it is open to grave question whether the ferment of malt (diastase) is not much impaired by the action of the alcohol to which it is exposed when dissolved in a fortified wine, such as port or sherry.

The medicated wines are open to the same objection to an even greater extent. The use of such liquors by an invalid on his own responsibility, or even by prescription, exposes him to great danger of becoming by degrees the unconscious victim of alcoholism, and, in the case of the coca wines, of the cocaine habit as well. On every ground their manufacture and sale should be strongly deprecated by the medical profession. (See also p. 559, footnote.)

¹ The quantity of bouillon represented by a wineglassful of such a wine varies from about 4 tablespoonfuls to 1½ teaspoonfuls (*Brit. Med. Journ.*, 1909, i. 795).

² *Brit. Med. Journ.*, 1909, i. 795.

³ Meat Port Nutrient is peculiar in containing about 1½ to 3 per cent. of uncoagulated proteid of beef-juice (*Lancet*, 1908, ii. 242).

⁴ See also Coley, *Brit. Med. Journ.*, 1898, ii. 715.

Non-Alcoholic Grape Wines are now made which consist of pure grape juice preserved by pasteurization ('Mostelle,' 'Vindevie,' 'Salvator Brand,' etc.). Suitably diluted, they form pleasant and refreshing drinks, useful for quenching thirst in fever and possessed of slight laxative and diuretic properties.¹

ACTION AND USES OF WINES.

Influence on Digestion.—Wines have a much more powerful inhibitory effect on salivary digestion than mixtures of alcohol and water of similar strength. Roberts,² for example, found that if even 1 per cent. of sherry or hock were present in the digesting mixture, the conversion of starch was almost brought to a standstill. This effect of wines is entirely due to their acidity. The experiments of Aitchison Robertson³ showed that a claret of 0.75 per cent. acidity had a markedly retarding effect on salivary digestion, while the influence of a sherry of 0.54 per cent. and a port of 0.42 per cent. was very much less. Chittenden and Mendel confirmed these results. The inhibitory effect of wines is lost when their acidity is neutralized. Hence, it is an obvious advantage, from a digestive point of view, to mix the more acid wines with an alkaline aerated water.

On *gastric digestion*, also, wines exert a retarding effect out of all proportion to the amount of alcohol they contain. The cause of this is not clear. According to some writers, it depends upon their solid ingredients. Roberts attributes it, in part at least, to some of the volatile constituents. Sherry and port seem to have a more powerful effect than claret or hock. Half a pint of sherry in 2 pounds weight of stomach contents is sufficient to produce a very pronounced degree of inhibition, and yet this is a not infrequent allowance. A pint of claret or hock is also enough to produce distinct effects. Effervescing wines, on the other hand, such as champagne, are much more feeble in their results, probably because the gas which escapes from them churns up the contents of the stomach mechanically.

'The effect of wines on *pancreatic digestion* is akin to their action in the mouth, and may be entirely explained by their acid qualities' (Chittenden).

It must be remembered that the above remarks apply only to the effects of wines upon the *chemical* processes of digestion.⁴ As in the case of alcohol, it by no means follows that the net result of taking wine with meals is unfavourable; for, by the increase of appetite

¹ For analyses see the *Lancet*, 1903, ii, 761. They are supplied by Reinheimer and Co., Surbiton, Surrey; J. Roubourdin, 1, East India Avenue, E.C. 1; Schweppes, Ltd., and others.

² 'Digestion and Diet,' p. 117.

³ *Journ. of Anat. and Physiol.*, 1898, xxxii, 615.

⁴ The conclusion drawn from experiments made by a Special Commission on light wines (*The Hospital*, 1907, xlii, 285) is that such wines, in quantities of from 8 to 10 ounces, are 'in no sense inimical to digestion.'

and gastric secretion which they induce, they may, in moderate quantity at least, not only neutralize any inhibition of the merely chemical processes which they exert, but actually render digestion quicker and easier than it otherwise would be. This, indeed, is one of the most useful actions of wines both in health and disease.

General Action of Wines in Health.—‘The conventional value of wine is determined less by its principal ingredients than by the prominence of the specific character termed *bouquet* and the absence of certain faults. Dietetically, most wines are of equal value provided they are the products of a favourable season, pure and free from the faults produced by fungi’ (Thudichum).

‘I have purposely made no attempt to answer the question so frequently and so uselessly put, “Why is one kind of wine better than another?” Every constituent helps to promote excellence: alcoholic content, bouquet, and every non-volatile ingredient. One wine is liked on account of its aroma, another on account of its strength, a third simply because of its flavour’ (Mulder).

These two quotations contain the gist of most that can be said as to the action of different wines on the human body. Nevertheless, they do not embrace quite the whole truth. We may admit that, for the purposes of dietetics, most sound wines are equally good as long as their alcoholic strength is the same, and that the æsthetic qualities determine their market much more than their hygienic value; but it must be remembered that a wine may contain ingredients which elude chemical analysis, but which are yet not without influence upon health, for, as has been truly said, ‘the human brain and the human stomach are the only analysts which never makes mistakes.’

The subject is further complicated by the fact that different constitutions react very differently to the same wine, a fact which must be within the experience of everyone. To some extent this may be explained by difference of habits, the sedentary man, for example, requiring to be much more sparing in his use of certain wines than his fellow of more active pursuits; but this does not account for all the facts, and much must be put down to what, for want of a better name, one can merely describe as idiosyncrasy.

In endeavouring to get further light on the subject, we shall do best to consider the effects of the principal constituents of wines on the body individually, and afterwards attempt to deduce from the results of that study some general rules for our guidance in recommending wines in health and disease.

Alcohol.—As a general rule, the stimulating action of any wine

depends chiefly upon the amount of alcohol which it contains. Now, the natural wines only contain about half as much alcohol as the strong or fortified wines, so that two bottles of good claret or hock are about equal, as far as alcohol is concerned, to one bottle of port or sherry.

Roughly speaking, then, the stimulating action of a fortified wine may be regarded as twice as great as that of a natural wine. This, however, is not necessarily quite true in any given case. Wines cannot be regarded as mere mixtures of alcohol and water in different proportions. For one thing, the mere fact of dilution is of importance. The more dilute the alcohol is, the more slowly it will be absorbed, and the less the chance of a large quantity of it reaching the tissues at one moment. The ethers and other volatile constituents, too, have a certain modifying influence upon some of the actions of alcohol, and a wine which is rich in these elements may be expected to have a different effect from another which is devoid of them, even although the two are of equal alcoholic potency. Notwithstanding this, and when all due weight has been given to such modifying factors, one is pretty safe in concluding that it is only the weaker, *i.e.*, natural, wines which are adapted for habitual use as accessories of the diet. We have further learnt that from 1 to 2 fluid ounces of alcohol is about the amount which can be safely taken in one day. Now, 2 fluid ounces of alcohol are contained in one bottle of good claret or hock, and therefore we may conclude that half a bottle daily of such wines is the limit for a sedentary individual, and a whole bottle is enough for a man of more active life. The fortified wines, on the other hand, should be reserved for special occasions, or should only be used as medicines under medical advice.

Acids.—We have seen that acids are an indispensable ingredient of all wines, and that they are chiefly present in the form of bitartrate of potash, but that some wines contain a certain proportion of volatile acids, such as acetic, in addition. To the healthy man the amount of acid present in any reasonably sound wine may be regarded as harmless, but it is generally believed that wines with a high degree of acidity may be injurious to some constitutions, and especially to the gouty and the rheumatic. It is doubtful whether this proposition can be maintained in such an absolute form. One must remember that the organic acids and their salts contained in wine are converted in the body into alkaline compounds, and are excreted as such. Certainly bitartrate of potash increases very appreciably the alkalinity of the urine. It is difficult to see, there-

fore, how its presence in wine can be other than beneficial, as far as gravel, at least, is concerned. As a matter of fact, Liebig long ago pointed out that the free use of hock (a rather acid wine) tended to prevent the precipitation of uric acid in the urine. The same is true of cider. Those who drink largely of it are not troubled with gravel; indeed, they are stated to enjoy a special immunity from that disease, for it not only renders the urine less acid, but increases its volume, so much so, indeed, that in Normandy the young and inexperienced practitioner is constantly diagnosing an imaginary diabetes.

It may be objected that, although this may all be true as regards the deposit of uric acid in the urinary passages, yet the acidity of wines may render them harmful in the tissues before the oxidation of their organic acids into alkaline forms has had time to take place. Even this, however, is very far from being proved, and Luff has shown¹ that, as a matter of fact, the most acid wines are *not* those which are most generally credited with being producers of gout. The supposed connection, indeed, between variations in the alkalinity of the blood and the occurrence of gout has probably been exaggerated, and demands much further investigation.

The action of the **tannin** in wine must be sharply distinguished from that of its other organic acids. A *rough* or *astringent* and an acid wine are by no means the same thing, though there can be little doubt that the former is often mistaken for the latter. The red wines, as a class, are richer in tannin than the white, and port, especially when young, is one of the richest of all. Burgundy, on the other hand, does not seem to contain a large amount of this constituent. Owing to this property, red wines may be useful in diarrhoea and harmful to the constipated, but it is a mistake to suppose that the mere presence of roughness or astringency (*i.e.*, of tannin) in a wine confers upon it any special strengthening qualities.

Sugar.—There can be little doubt that the craze at present is for *dry*, *i.e.*, sugar-free, wines. It is interesting to inquire whether this can be justified. We have seen that the total amount of sugar which can be consumed daily in the form of wine, no matter how sweet, is so small that it can be neglected from a merely nutritive point of view. The further question therefore arises, Is the comparatively small quantity of sugar, which even the so-called 'sweet' wines contain, in any way injurious to health? Here, again, it is the gouty who are believed to be subject to special risks. There is no more reason, however, to believe that the sugar of wines, *per se*,

¹ 'Gout: its Pathology and Treatment,' Cassell and Co., 1898.

is any more harmful to such persons than their acids are. It is interesting to note in this connection that it is the fortified wines which, as a class, are the sweet wines, and the natural wines which (with a few exceptions) are *dry*, and the suspicion naturally arises that it is the greater amount of alcohol in the sweet wines which renders them dangerous to the gouty (even granting that such danger has been proved to exist), rather than the sugar which they also contain.

It is probable, indeed, that it is the combined presence of both sugar and acid in a wine which renders it harmful to the class of whom we are speaking rather than either of these ingredients alone. There is certainly some reason to believe that such a wine is more apt to excite an 'acid' dyspepsia in gouty subjects than dry wines are. This may perhaps be due to the rapid absorption of sugar from the stomach in the presence of alcohol, and its replacement by a large quantity of highly acid gastric juice. It may perhaps be the case, too, that fermentation is apt to be restarted in a fortified wine once its alcohol is diluted in the stomach, and that this may give rise to the production of acid substances. Be the explanation what it may, the gouty man does well to avoid the fortified wines unless very dry, for such a dyspepsia is prone to be the signal for an attack of gout.¹

The action of the *extractives* of wine on the body is obscure. It has been supposed by some that their influence is akin to that of the extractives of meat, and they are believed to help in the making of blood. It may be worth while remembering that extractives are most abundant in old wines and those of good vintage.

¹ The *Lancet* (1899, i. 525) gives the following list of practically sugar-free liquors which may be recommended to diabetics and the gouty :

	Per Cent. of Sugar.	
Champagne 'Sans Sucre' (Hertz and Collingwood)	..	0'2
Californian Burgundy (Haig, Smith and Co., Manchester)	..	0'15
" Claret " "	..	0'14
Australian Burgundy (Burgoyne)	..	0'28
South Australian wines (Orion Brand, E. Burney Young, 35, Walbrook Street, E.C.):		
Cabernet	0'14
Burgundy	0'16
Reisling	0'20
Dry Imperial Champagne (Moët and Chandon)	..	0'65
Cider (Gaymer and Son)	0'7 to 2'12
Harvey's Pale Ale	None.
Back and Co.'s Anti-diabetic Non-acid Whisky	..	"
Dewar and Sons	"
Vibrona Champagne	0'13
" Sherry	0'20
Vitali's Italian wines	0'11 to 0'17

The *volatile constituents* of wine include the ethers and essential oils, the latter, along with certain highly-oxidized aldehydes, being probably chiefly responsible for the quality known as 'bouquet.' The action of these upon the body in health is probably slight, though they may exercise a modifying influence upon the intoxicating tendency of the alcohol along with which they occur. In disease, on the other hand, the ethers, and especially their volatile members, seem to have often a most valuable stimulating influence on the exhausted brain and heart.

In attempting to summarize the points which have been raised in this discussion as to the use of wines in health, I cannot do better than quote the conclusions of Anstie:¹

1. Wines for daily use by healthy adults should not on the average contain more than 10 per cent. absolute alcohol (by weight); 8 or 9 per cent. is better.

2. If wine be used as the daily drink, it is best, as far as may be, to use only one kind at a time and no other form of alcoholic liquid.

3. Sound natural wines are to be obtained at the best economic advantage from the Bordeaux district; the red wines are to be preferred.

4. Rhine wines (white) are equally excellent, but more expensive.

5. Hungarian wines are also in many instances excellent, but they are unequal in quality owing to defects of manufacture.

6. Greek wines labour under the same defects.

7. The fortified wines, as a class, develop no proper vinous qualities till they have been for some years in bottle. Sherry, however, is greatly superior to the other wines of this class in the rapidity with which it develops the volatile ethers.

8. Fortified wines in small quantities, especially sherry, for the reason just named, are the appropriate stimuli of certain kinds of infantile and youthful debility, and of the enfeebled nervous system of old persons.

9. Half a bottle of a natural wine a day for a sedentary and a bottle a day for a vigorous and actively-employed adult affords a reasonable and prudent allowance of alcohol, and this quantity of wine, either alone or with water, will be enough to satisfy the needs of moderate persons for a beverage at lunch and dinner, the only two meals at which alcohol should, as a rule, be taken.

The use of wines in disease will be considered in subsequent chapters.

¹ 'On the Uses of Wines in Health and Disease' (Macmillan and Co., 1877), p. 39.

CHAPTER XXII

THE COOKING OF FOODS¹

THE object of cooking food is twofold :

1. *Æsthetic*—to improve its appearance and to develop in it new flavours.

2. *Hygienic*—to sterilize it to some extent and to enable it to keep longer.²

It is an error to suppose that cooking increases the digestibility of food. That is only true of vegetable foods. The digestibility of animal foods is diminished rather than increased by cooking. This is true at least of the *chemical* processes of digestion, though the increased attractiveness of well-cooked food may render it indirectly more capable of digestion by calling forth a more profuse flow of psychical gastric juice (see p. 417).

The application of heat in some form or another being the essential part of all ordinary processes of cooking, it is important to have clear ideas as to the effect of heat upon the different chemical constituents of food.

The effect of heat on the *proteins* of the food is to coagulate them. It would be a complete mistake, however, to suppose that a boiling temperature is essential for bringing about this change, for all proteins, both animal and vegetable, are coagulated if their temperature be raised to 170° F. We shall subsequently see that ignorance of this fact is a fertile source of errors in cooking. If the temperature be raised much above this point, the protein tends to shrink and harden, and the digestibility of the food in which it is contained is proportionately lessened.

Of the *carbohydrates* of the food, starch is most affected by heat.

¹ The reader may also consult on this subject 'The Chemistry of Cookery.' by W. Matthieu Williams (London, Chatto and Windus, 1892); Thudichum's 'Spirit of Cookery' (London, Baillière, Tindall and Cox, 1895); and Sir Henry Thompson's 'Food and Feeding,' ninth edition (London, Frederick Warne and Co.), chapters v. and vi.

² No animal parasite found in meat is capable of withstanding a temperature of 70° C. All ordinary forms of cooking will therefore render meat free from this source of infection. On the other hand, many pathogenic bacteria, such as those of splenic fever, malignant œdema, septicæmia, and chicken cholera, if present in the interior of meat, might quite easily escape being killed by the temperatures usually reached in ordinary methods of cooking.

Dry heat converts starch into a soluble form, and ultimately into dextrin. This change occurs to a limited extent in the crust of bread, and also in the making of toast. Moist heat causes the starch grains to swell, and ultimately to rupture their cellulose envelopes, and the starch is then said to be *gelatinized*. That this change also takes place considerably below the boiling-point of water is shown by the following table of the *gelatinization-points* of different kinds of starch :¹

Oat ..	..	..	..	185° F.
Barley ..	..	..	..	176° F.
Rye ..	..	..	..	176° F.
Wheat ..	..	..	..	176° F.
Rice ..	..	..	..	176° F.
Maize ..	..	..	..	167° F.
Potato ..	..	..	..	149° F.

Here again one sees that in the case of some starchy foods, at any rate, the change which it is the object of cooking to effect can be brought about at a comparatively low temperature.

The effects of heat upon *sugar* have already been described, and it need only be mentioned here that the partial conversion of sugar into caramel is one of the means by which flavour is developed in food by cooking.

The *fats* of food are not so much affected by heat as the proteins and carbohydrates. At high temperatures, however, as when one of the dry methods of cooking is employed, some at least of the fat may perhaps undergo a partial decomposition, with the liberation of free fatty acid.² This may explain why it is that hot fat is so much more apt to prove irritating to the stomach than cold fat, for it is not improbable that the fatty acid may reunite with glycerine to form neutral fat on cooling. Fat which has been heated and allowed to cool again is often found to have become more granular than it was before. This change is probably due to the driving off of water, and it tends to render the fat more brittle, and consequently more digestible than it was before. The change is well exhibited in the case of dripping, and also in fried bacon.

With these preliminary considerations we may proceed to the study of the effects of cooking upon animal and vegetable foods respectively.

I. COOKING OF MEAT.

The ideal to be aimed at in cooking meat is to decompose its red colouring matter (hæmoglobin), so as to remove its raw appearance,

¹ From Sykes' 'Principles and Practice of Brewing,' p. 70.

² See also Matthieu Williams' 'Chemistry of Cookery,' p. 158.

and to do this without overcoagulating the solid proteins of the meat or removing from it its flavouring ingredients (extractives).

We may glance very briefly at the means by which this ideal is to be attained in the ordinary methods of cooking.

1. **Boiling.**—It is unfortunate that the term 'boiling' should be applied at all to any method of cooking meat, for it implies that the subjection of the meat to the temperature of boiling water (212° F.) is an essential of the process. But this, for the reasons indicated above, is a mistake. The red colouring matter of the meat is decomposed and rendered brown at a temperature considerably below that of boiling water, and by going up to the boiling-point one runs the risk of hardening the meat by overcoagulation of its proteins.

That the boiling-point is not essential for the complete coagulation of the proteins can be most easily proved in the case of an egg. If two eggs are taken, and one kept in water at a temperature of 175° F. for ten or fifteen minutes, and the other for an equal length of time in boiling water, it will be found at the end of the experiment that the contents of both are solid throughout, but that in the case of the former they consist of a tender jelly, whereas in the boiled egg they are dense and almost leathery. Several so-called egg-boilers, indeed, have now been introduced which go upon the correct principle of cooking the egg at a temperature considerably below the boiling-point of water.

Now, what is true of an egg holds good also for meat, and accordingly the first principle to be observed in the 'boiling' of meat is to see that the temperature of the water does not rise much above that which is required for the coagulation of proteins. It is only by giving heed to this that one can achieve the first result desired—the abolition of the raw colour of the meat with avoidance of overhardening.

The second object to be aimed at, that of retaining all the flavouring constituents of the meat, also demands some care. The flavour of meat is due to its extractives and salts, and both of these are readily dissolved by water. If the water in which the meat has been cooked is to be consumed in the form of soup, the partial removal of some of these flavouring ingredients is not of much importance; but if the meat alone is to be eaten, precautions must be taken to prevent their being dissolved out.

One way of doing this is to use as *small a quantity* of water as possible; for the larger the proportion of water to meat, the greater

will be the amount of soluble substances removed. The quantity of water, therefore, should be just sufficient to cover the meat, and no more.

The other way of obviating removal of soluble substances is to *seal up* the piece of meat. This is best achieved by plunging it into *boiling* water, and leaving it there for a few minutes. This causes a rapid and complete coagulation of the protein in the fibres of the meat, which forms an almost impermeable layer on the surface, and shuts in the soluble constituents.¹ When this has been done, the temperature of the water should be lowered, and the process of cooking continued slowly.

2. In the process of *roasting* the heat is conveyed to the meat by direct radiation, instead of through the medium of water. Here, again, high temperatures should be avoided, except at the outset, when it is necessary to effect a sealing of the surface, for the same reason as in boiling. If the piece of meat be thin, the high temperature to which it is first exposed not only seals the surface, but also coagulates the protein throughout the whole thickness, so that the meat is practically cooked at once. This happens, for instance, when a chop is cooked on the grill, and the completeness of the sealing is shown by the fact that the water vapour produced from the fluids in the meat is unable to escape, and by its expansion causes the chop to assume that puffy form which is a sign of skilful cookery. In the case of a large joint the heat does not penetrate with sufficient rapidity to admit of instantaneous cooking, and in that case a long exposure to a lower temperature is required after the surface has once been sealed. Desiccation of the meat during this period is prevented by continuous basting, which forms a sort of impenetrable varnish of fat over the surface. Roasting, if properly performed, not only prevents the escape of the natural flavourers of the meat, but develops in it substances which are themselves of a sapid nature. This is due to a change which it brings about in the extractives on the surface, analogous to the alteration which sugar undergoes in its conversion into caramel. This results in the production of the dark-brown, sticky substance on the surface of a roast joint which is familiar to everyone, and which is sometimes termed *osmazone*. It is one of the most sapid substances known.

¹ Recent experiments in America, however, have shown that if meat be cooked in water at 80° to 85° C., placing the meat in hot or cold water at the start has but little effect on the amount of material found in the broth (U.S. Dept. of Agriculture, Off. of Experiment Stations, Bull. No. 141, 1904).

Experiments which have been made in America¹ show that roasts are cooked as quickly at a temperature of 175° C. as at 195° C. This is of practical importance from the point of view of economy in fuel. When cooked at 100° C., a very much longer time is required to raise the inner temperature from medium (62° C.) to well-done (72° C.) than to cause the same rise at 195° C. or 175° C. There is, therefore, much less danger of over-cooking the meat at this temperature (100° C.).

3. **Baking** acts in precisely the same way as roasting, the heat in that case being applied all round the meat at once, instead of only to one side at a time. The production of osmazone by this process is, however, rather limited.

4. **Stewing** is in many respects the ideal method of cooking meat. If properly performed, it coagulates without overhardening the proteins, while, owing to the fact that the juice is eaten along with the meat, none of the flavouring ingredients are lost. At the same time, the prolonged action of heat and moisture converts most of the connective tissue into gelatin, so that the fibres readily fall apart and the meat becomes very tender. Here, again, the secret of success consists in avoiding too high temperatures. It is not sufficient to place the pan by the side of the fire, and allow it to 'simmer' instead of 'boil.' The use of a thermometer will show that the temperature of 'simmering' and 'boiling' water is really the same, *i.e.*, 212° F., the only difference being that in the former case the heat is reaching the water more rapidly and more of it is wasted. In proper stewing the temperature should not be allowed to rise above 180° F.

2. COOKING OF FISH.

The flavouring ingredients of fish are even more easily dissolved out by water than those of meat; and as fish has less flavour to start with, any loss is the more carefully to be avoided. For this reason boiling, unless very carefully performed on the lines above laid down, is not a suitable method of cooking fish. The experiments of Sir Henry Thompson² show that even when carefully performed it is apt to result in a loss of at least 5 per cent. of solid matter. For this reason cooking by means of water-vapour (steaming) is preferable, just as it is in the case of some vegetables.

¹ 'A Precise Method of Roasting Beef.' The University Studies (Urbana, Ill., U.S.A.), vol. ii., No. 4, May, 1907.

² 'Food and Feeding,' p. 196.

Frying is a method of cooking specially applicable to some forms of fish, and demands a special word of description, especially as the process is so often misunderstood.

The essence of frying consists in the sudden exposure of the object to be cooked to a very high temperature. This has the effect of producing an instantaneous coagulation of the proteins on the surface, along with a slight degree of charring. Any escape of soluble substances is thus prevented, while the surrounding temperature is so high that the fish or other substance is practically cooked throughout its whole thickness almost instantaneously.

In order to attain this very high temperature, some form of fat must be used as a medium. Olive-oil or good cottonseed-oil are best. The oil should be heated in a deep pan almost to its boiling-point (the actual temperature is about 350° to 390° F.); and when this temperature has been reached the object to be fried should be suddenly plunged into the pan, and left for two or three minutes. The sputtering which ensues is due to the sudden conversion of the moisture on the surface of the object into steam. When this has ceased the cooking will be complete, and the object should be lifted out and the excess of oil allowed to drain off.

It will be observed that this process differs entirely from the so-called 'frying' usually practised in this country, in which the fat employed is regarded merely as a means of preventing the object from adhering to the surface of the shallow pan, in which a sort of roasting is really accomplished.

3. COOKING OF VEGETABLE FOODS.

In the cooking of vegetable foods the objects to be achieved are different from those which one seeks to accomplish in the case of animal foods. Cellulose and raw starch are almost incapable of digestion by man, and hence the softening and rupture of the cellulose framework of a vegetable food and the gelatinization of its starch grains are the chief ends which it is the purpose of cooking to bring about.

Cellulose can be softened, and, indeed, partly converted into sugar, by the action of acids, aided by heat. This is Nature's method of dealing with it. In its unripe state a pear or other fruit is hard and 'woody' from the presence of a cellulose framework. In process of ripening the acids in the fruit, aided by the heat of the sun, effect a softening of this framework, with partial or complete solution of the cellulose fibres, the product being the sweet and soft ripe fruit.

This method is sometimes unconsciously imitated by man. The process of preparing *ensilage* is an example of it. Here, under the influence of fermentative bacteria, acids are produced in grass which, by the aid of moisture and heat, act upon the cellulose, and effect a partial conversion of it into sugar. In Germany a very similar process is employed in the conversion of cabbages into *sauer-kraut*.¹

The preparation known as *sowans* is an example of the operation of a similar agency on the cellulose of oatmeal. Ordinary porridge, also, when allowed to stand for some time, becomes a soil for the growth of acid-forming bacteria, and the products of the growth of these bring about some degree of softening of the cellulose in the particles of oatmeal. For this reason porridge is often found to be more digestible when stale than when perfectly fresh.

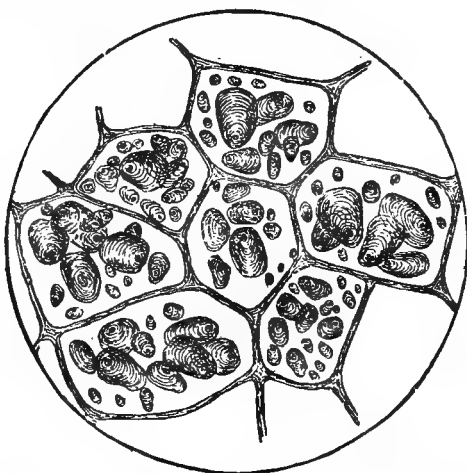


FIG. 29.—CELLS OF A RAW POTATO, WITH UNRUPTURED STARCH GRAINS AND CELLULOSE FRAMEWORK.

Another way of overcoming the cellulose obstacle, which may in a sense be regarded as a process of cooking, is by *milling* or *grinding*. This breaks up the cellulose framework, and allows the digestive juices to penetrate into the nutritive ingredients which it encloses.

More commonly, however, one finds the same object accomplished by the combined action of heat and moisture. When exposed to

¹ It is denied by some that cellulose is really acted upon by acids, and they attribute the results obtained in the above instances to the action of other agencies.

moist heat starch grains, as we have seen, swell up, their envelopes rupture, and they run together to form a paste or starch jelly. As

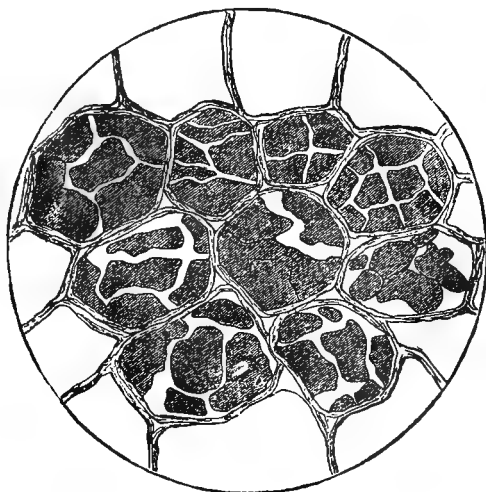


FIG. 30.—CELLS OF A PARTIALLY COOKED POTATO, THE STARCH GRAINS RUPTURED.

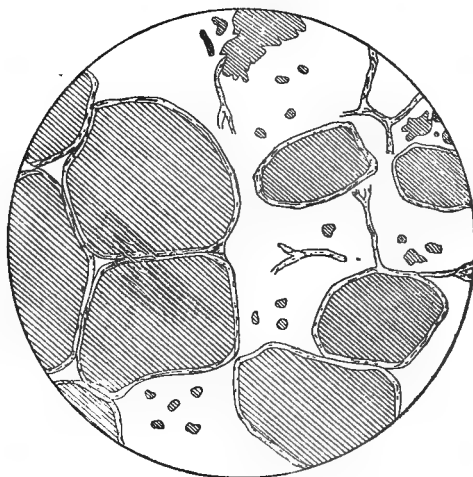


FIG. 31.—CELLS OF A THOROUGHLY BOILED POTATO; CELLULOSE FRAMEWORK BROKEN DOWN.

this jelly expands it presses upon and ultimately ruptures the framework of cellulose in which the grains are enclosed, and in this way the two chief objects aimed at are achieved. The degree to which

this occurs in different cases is very well shown in the accompanying diagrams (Figs. 29, 30 and 31), which illustrate the action of moisture and heat upon the structure of a piece of potato.

It will be evident from these considerations that cooking is of immense importance in facilitating the digestion of vegetable foods, and the larger the proportion of cellulose present, the more essential does thorough cooking become.

On the *proteins* of vegetables heat has an effect precisely similar to that which it exerts on the same constituent of animal food; that is to say, they become coagulated. Now, the coagulation of proteins is accompanied by shrinkage rather than by swelling, and for this reason, if the cellulose framework encloses protein only, it does not become ruptured; and one can therefore readily understand that if a vegetable food contained protein only its digestibility would be affected by cooking in a precisely similar way to that of animal food; in other words, it would be rendered less rather than more digestible by the process. As a matter of fact, however, there are few vegetable foods which do not contain much starch as well as protein, and hence it is that the general rule holds good that cooking increases their digestibility.

LOSSES IN COOKING.

No matter how carefully cooking is performed, a certain amount of loss of the soluble constituents of the food during the process is almost inevitable. In the case of meat, it has been found by Johnston that—

	<i>In Boiling.</i>	<i>In Baking.</i>	<i>In Roasting.</i>
4 lb. of beef lose in weight ..	1 lb.	1 lb. 3 oz.	1 lb. 5 oz.
„ mutton lose in weight ..	14 oz.	1 lb. 4 oz.	1 lb. 6 oz.

By far the larger part of this loss, however, is due to water. This is shown by the following analyses given by König :

COMPARATIVE COMPOSITION OF MEATS BEFORE AND AFTER COOKING.

	<i>Water.</i>	<i>Nitrogenous Matter.</i>	<i>Fat.</i>	<i>Extractive Matter.</i>	<i>Salts.</i>
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Beef :					
Before cooking (raw) ..	70.88	22.51	4.52	.86	1.23
Same after boiling ..	56.82	34.13	7.50	.40	1.15
Same after broiling (as beefsteak)	55.39	34.23	8.21	.72	1.45
Veal cutlets :					
Before roasting (raw) ..	71.55	20.24	6.38	.68	1.15
Same after roasting ..	57.59	29.00	11.95	.03	1.43

The actual loss of soluble matter is more clearly brought out when these figures are recalculated on the basis of dry substance :¹

¹ Bulletin 21, United States Department of Agriculture, p. 87.

COMPARATIVE COMPOSITION OF WATER-FREE SUBSTANCE
OF MEATS BEFORE AND AFTER COOKING.

		Nitrogen.	Nitrogenous	Fat.	Extractive	Salts.
		Per cent.	Matter. Per cent.	Per cent.	Matter. Per cent.	Per cent.
Beef:						
Before cooking ..	..	12.37	77.31	15.47	2.98	4.24
After boiling ..	..	12.65	79.06	17.38	.90	2.66
After roasting ..	..	12.27	76.73	18.41	1.59	3.27
Veal cutlets:						
Before cooking ..	..	11.39	71.17	22.45	2.32	4.06
After roasting ..	..	10.93	68.36	28.18	.09	3.37

It will be observed that the loss is entirely confined to the extractive matter and salts.

As far as their soluble constituents are concerned, vegetable foods behave similarly, the loss of salts especially being often very considerable. This point, however, has been fully dealt with when the composition of vegetable foods was described.¹

As regards water, the behaviour of the two classes of foods on cooking is entirely different, for vegetable foods tend to become richer in water when cooked, instead of losing it. The contrast between the two in this respect is very well shown in the following figures given by Forster :

COMPARISON OF THE EFFECTS OF COOKING ON THE PROPORTION OF WATER IN ANIMAL AND VEGETABLE FOODS.

	Raw.		Cooked.
Beef ..	.. 75 per cent.	Boiled ..	.. 55 to 59 per cent.
		Roast ..	.. 56 to 63 ..
Veal ..	.. 78 ..	Roast ..	.. 60 to 64 ..
Flour ..	.. 12 to 14 per cent.	Bread ..	.. 36 to 40 ..
		.. chewed	.. 70 per cent.
Peas ..	.. 14 per cent.	Peas brose ..	.. 68 to 78 per cent.
		Pea soup ..	.. 90 per cent.
Potatoes ..	.. 75 ..	Potato purée ..	.. 78 ..
		.. soup ..	.. 91 ..
Cabbage ..	.. 87 ..	Cabbage ..	.. 85 to 90 per cent.

One may, therefore, lay it down as a general proposition that animal foods become less watery as the result of cooking, while vegetable foods, on the contrary, become more watery.

This is another explanation of the different effect which cooking exerts on the digestibility of the two classes of foods. The concentration which meat undergoes when cooked is unfavourable to digestion, while the dilution of the vegetable foods after cooking makes less demand on the digestive juices. This, too, is one reason why meat which has been cooked more than once is rather difficult of digestion. Not only are its proteins apt to be over-coagulated, but

¹ See also United States Department of Agriculture, Bulletin 43, 'Losses in Boiling Vegetables,' etc.

the relative proportion of fat is increased at the same time, and both of these facts militate against rapid and easy digestion.

On the other hand, the increase of bulk which vegetable foods undergo as the consequence of taking up water in the course of cooking is apt, for reasons already explained, to throw a strain on the *mechanical*, as opposed to the purely chemical, functions of the digestive organs. The bearings of this fact upon the practice of vegetarianism have been discussed at length in an earlier chapter.

COMPOSITION OF SOME COOKED VEGETABLE FOODS (EXCLUDING PROTEIN).¹

Names.	Water.	Fat.	Woody Fibre.	Starch.
Semolina	90·17	0·08	0·04	7·24
Sago	89·00	0·04	0·01	9·35
Oswego	87·32	0·02	0·01	9·68
Vermicelli	87·14	0·01	0·07	10·82
Arrowroot ²	93·41	Trace	0·01	4·83
Benger's Food, cooked with milk ³	88·30	2·57	0·23	8·17
Quaker Oats	92·48	0·32	0·09	6·25
Provost Oats	88·44	0·36	0·16	9·00
Farola (fine grain)	90·24	0·02	0·06	7·22
Farola (large grain)	86·08	0·01	0·15	11·06
Florador (large grain)	89·45	0·01	0·08	8·67
Granola	87·40	0·03	0·10	9·42
Farola (medium grain)	89·15	0·01	0·06	8·89
Pearl barley	85·01	0·07	0·10	12·98
Mother's oats	89·72	0·45	0·15	8·70
Hominy	86·63	0·09	0·16	9·87

APPROXIMATE COMPOSITION OF EDIBLE PORTION OF SOME COOKED VEGETABLE FOODS.

	Water.	Ash.	Protein N×6·25.	Fat.	Fibre.	Starch.
Banana flour	91·91	0·31	2·30	0·06	0·18	5·03
Soya beans	66·14	1·23	16·00	6·05	3·08	7·65
Green flagorets	62·77	0·92	12·56	0·88	2·88	21·22
Plasmon arrowroot	92·90	0·22	0·81	0·01	0·01	6·12
Provost barley	90·53	0·13	2·88	0·04	0·09	6·61
Provost barley and oats	85·17	0·27	2·68	0·42	0·30	11·02
Asparagus	92·18	1·31	1·76	0·37	0·52	4·44
Frame food	93·85	0·27	0·72	0·82	0·08	4·63
Boyd's banana food	88·33	0·56	3·90	0·38	0·14	6·26
Rice	71·88	0·10	1·92	0·05	0·09	27·07
Celeriac	94·41	0·42	0·95	0·15	0·90	2·82
Butter beans	63·94	1·21	8·96	0·82	2·68	21·67
Chicory	94·59	0·32	1·42	0·10	0·51	2·99
Chestnuts	71·08	0·64	3·59	0·81	1·54	23·46
Borecole (Scotch kale, curly greens)	89·05	0·83	3·71	0·73	1·08	3·94
Endive	95·43	0·55	0·52	0·23	0·71	2·73
Revalenta arabica	94·30	0·15	1·19	0·03	0·07	4·38

¹ From analyses by Miss Katherine J. Williams. ² West Indian, 1s. 4d. per lb.

³ Cooked according to directions on tin—1 tablespoonful first mixed, 4 table-spoonfuls of cold milk, then a pint of boiling milk and water added ($\frac{1}{3}$ water, $\frac{2}{3}$ milk). All the rest of the foods were cooked with water alone.

SLOW COOKING.

Food being a bad conductor, heat only penetrates into it very slowly. Wolffhügel and Hüppe,¹ for instance, found that the temperature of the interior of a piece of meat weighing 9 pounds after four hours' boiling was only 88° C., or 12° below the boiling-point of water. The interior temperature of a roast varied from 70 to 95° C., according to size. Similar observations have been made by Sir Henry Thompson.² He found that the temperature close to the bone of a leg of mutton which had been boiled or roasted for some hours was never above 186° or 187° F.

Hence it is that, if heat be applied to a piece of meat too rapidly, one simply wastes fuel and runs the risk of overcooking the outer layers. It is far better to allow a moderate amount of heat to act on the meat for several hours, and the longer the time allowed, the lower will be the temperature required, always assuming that it is kept above the coagulation-point of proteins. Various special forms of apparatus have been invented with the view of economizing fuel, and allowing of the prolonged action of a moderate degree of heat, some of which are certainly not as well known as they deserve to be.

The simplest of these are constructed on the principle of an ordinary water-bath, and consist of a double pan, the outer being filled with water which is kept at, or near to, the boiling-point, while the article to be cooked is placed in the inner vessel. The heat only penetrates slowly to the latter, and never reaches the boiling-point, while any risk of burning is also prevented. The French *bain-marie* is constructed on this plan. *Warren's Cooking-pot* and *Bailey's Cookers*³ are also good examples of the application of the principle.

The *Duplex Boilervette*⁴ is a modification of the *bain-marie*, in which the steam from the outer pan is prevented from escaping and reaches a high temperature, so that the food in the inner vessel can be actually boiled.

Somewhat different from these is the *Norwegian Self-acting Cooking Apparatus*.⁵ This consists of an outer cylindrical vessel lined with non-conducting material, and an inner metal cylinder in which the object to be cooked is placed. If, for example, it is desired to boil a fowl, we place the latter in a saucepan of boiling water, boil it over the fire for five or ten minutes in order to 'seal up' the surface,

¹ Quoted in Bulletin 21, United States Department of Agriculture.

² 'Food and Feeding,' p. 97.

³ Bailey's Patent Cookers Company, 10, Bromley Road, Beckenham, Kent.

⁴ Manufactured by R. W. Welbank, North Newington, Banbury.

⁵ Supplied by Silver and Co., Sun Court, Cornhill, E.C.

then remove the pan from the fire and place it in the inner cylinder. The outer lid is then closed, and, the escape of heat being thus entirely prevented, cooking is allowed to go on slowly for several hours. On opening the apparatus after the lapse of twelve or eighteen hours, the fowl will be found steaming hot, and, though thoroughly cooked, quite tender throughout. The apparatus acts on the principle of entirely preventing any loss of heat, and just as it prevents any heat getting out, so it can with equal efficiency prevent any from getting in. It may, therefore, be used as a refrigerator, for keeping ices, etc., unmelted, quite as well as a cooker. The apparatus saves a great deal of time, trouble, and fuel, and is very useful to travellers and campers-out, or in any circumstances in which one wants hot food constantly ready.

A little reflection will show that, in the use of an ordinary oven, a great waste of fuel is inevitable, for the metal of which the oven is constructed is an admirable conductor, and allows heat to escape as fast as it gets in. In order to prevent this and the waste of fuel which results from it, all that is necessary is to have the oven covered with some non-conducting material. The heat supplied by the fuel will then be unable to escape from the oven, and will all be utilized to cook the food, instead of being to a large extent dissipated into the surrounding atmosphere.

An oven constructed on this plan was devised by Canon Moore Ede¹ for use in the preparation of penny dinners. The apparatus and its advantages are thus described by its inventor:²

‘It consists of a box 3 feet high, 2 feet wide, 1 foot 9 inches deep, with an outer case of sheet iron. The sides and lid are lined with $2\frac{1}{2}$ inches of felt, and inside this, again, is a further lining of tin. Underneath this box, which will hold 30 gallons, are placed two of Fletcher’s Atmospheric Gas Burners. The felt being a non-conductor, nearly all the heat from the gas is utilized, and a comparatively small expenditure of gas suffices to raise the temperature of the contents of the box to boiling-point, or to the heat required for the food which is being cooked.’³

‘When once the desired temperature is obtained, one of the burners can be turned off and the other lowered, when, owing to the prevention of radiation by the felt, it will be found that a merely nominal expenditure of gas will enable the temperature to be maintained for hours, and even when the gas is totally extinguished many hours will elapse before food cooked will become cool.

¹ Now Dean of Worcester.

² ‘Cheap Food and Cheap Cooking’ (London: Walter Scott), 1884.

³ Since the above was written, sundry alterations and improvements have been made which considerably increase the economy and efficiency of the apparatus

‘But except in the case of puddings which require rapid boiling, the cooking is done in an inner pan, which is placed inside the box, and which contains rather more than 20 gallons. The apparatus may be best described as a huge Warren’s pot, with the additional advantage that the whole of the inner pan is surrounded by warm water.

‘The space between the inner pan and the side of the box is filled with water, which is kept at the temperature desired by means of the gas burners.

‘The chief advantages of this apparatus are as follows:

‘Economy in first cost of the apparatus, which can be procured from Messrs. Emley of Newcastle.

‘There is little, if any, smell of cooking.

‘The apparatus can be placed in any room, and no arrangement of flues is required. The iron pipe which takes away the fumes of the gas can be carried into the chimney, if there is one in the room, or, if there is no chimney, through a small aperture in the window.

‘As the felt retains the heat, the exterior of the box remains cool, and the temperature of the room is scarcely affected; indeed, so slight is the smell of cooking, so little the heat radiated, that the apparatus might almost be placed in the schoolroom itself.

‘Owing to the inner tin and the box itself being firmly closed, no evaporation takes place, and all the nutriment and flavour of the food is preserved.

‘Surprising though it may sound, there is a gain of nearly 30 per cent. in quantity in the case of meat cooked in this way; in preparing soup less of the nutrition of the meat is lost, and vegetables are more palatable as well as more nutritious when cooked in the manner described.

‘Most food is improved by being cooked very slowly; this can be easily done by this apparatus, and also it can be so adjusted that each kind of food can be cooked at the temperature which most effectively brings out its nutritious qualities; this for meat is at about 170° F., for pulse about 200°.

‘The expenditure for fuel is very slight; gas costing seven-tenths of a penny will in this apparatus raise 5 gallons of water to boiling-point, and less than 3d. is sufficient to boil 30 gallons. Once boiled, the temperature can be retained at a nominal expenditure of gas.

‘Another advantage is that no food can be burned, and no care is required to prevent that very common catastrophe. The food once placed in the inner tin in proper proportions, and the space between the inner and outer case filled with water, the lid is closed and the gas turned on till the required temperature is reached; it is then

lowered, and the dinner is left to take care of itself. As it is often convenient to prepare the dinner the previous afternoon, it is not unfrequently left cooking at a low temperature the whole night. All the labour entailed by keeping up a coal fire is avoided, and also the constant attention usually necessary to prevent burning.

'The only defect of the apparatus is that it is not capable of baking, but in the case of school dinners I think this will be found of little consequence.'

The *Aladdin Oven*, invented by Dr. Edward Atkinson, is on the same principle. 'It is a simple

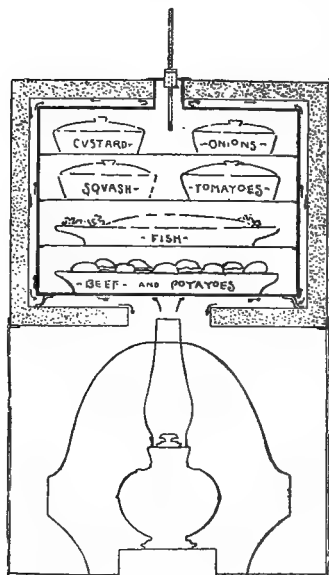


FIG. 32.—THE ALADDIN OVEN.
(AFTER ATKINSON.)

iron box, closed in front by a door, and having an opening in the top that communicates with a tube to let off any superfluous steam. This box is surrounded by another, whose top and sides are made of non-conducting material for the purpose of holding the heat. A standard, on which this box is set, and a lamp underneath complete the apparatus.¹

A clearer idea of the structure of the oven will be obtained from the accompanying diagram, borrowed from Dr. Atkinson's interesting book (Fig. 32).

The oven can be heated either by a kerosene lamp or by a small gas burner, and it will raise the temperature of 40 pounds of meat and 15 quarts of water to 180° F. in the space of seven hours, and if the lamp

is then removed the temperature undergoes no appreciable diminution for fully four hours.

Dr. Atkinson calculates that in an ordinary oven 2 pounds of fuel must be expended for every pound of food cooked, whereas in his apparatus 2½ pounds of fuel will cook 60 pounds of food, and that the daily cost of cooking by it amounts to only ½d. per person for a family of ten. The saving of trouble also is enormous, for the apparatus can be left to cook by itself overnight.

¹ Edward Atkinson, 'The Science of Nutrition and the Art of Cooking in the Aladdin Oven' (Boston, Damrell and Upham), 1896. See also 'How to Make and Use an Aladdin Oven,' by the same author and publisher (1901).

In 1889 and 1890 a number of experiments were made in America by Mrs. Ellen H. Richards and Mrs. Mary H. Abel on the best methods of cooking food. They state in their report¹ that 'for simplicity, effective use of heat, economy of fuel and development of flavour in the food cooked, combined with increase of its digestibility, the Aladdin Oven is an apparatus far exceeding in merit any other now in the market.' A friend of the writer's has used the oven for several years with the most satisfactory results, and his experience entirely bears out the favourable opinion expressed in the above report. The Aladdin Oven cannot be obtained ready made in this country, but it can easily be constructed by any intelligent tinsmith.

It is interesting to note that the advantages of slow cooking are well known to some savage tribes, and in this respect the civilized cook has something to learn from them.

This is the method of cooking practised by the Kanakas of the Friendly Islands, as described by the late Mr. F. T. Bullen:²

'A hole is scooped in the earth, in which a fire is made (of wood), and kept burning until a fair-sized heap of glowing charcoal remains. Pebbles are then thrown in until the charcoal is covered. Whatever is to be cooked is enveloped in leaves, placed upon the pebbles, and more leaves heaped upon it. The earth is then thrown back into the cavity and well stamped down. A long time is, of course, needed for the viands to get cooked through; but so subtle is the mode that overdoing anything is almost an impossibility. A couple of days may pass from the time of 'putting down' the joint, yet when it is dug up it will be smoking hot, retaining all its juices, tender as jelly, but, withal, as full of flavour as it is possible for cooked meat to be. No matter how large the joint is or how tough the meat, this gentle suasion will render it succulent and tasty; and no form of civilized cookery can in the least compare with it.'

No better illustration of the advantages of *slow* cooking could well be found.

¹ Bulletin No. 21, United States Department of Agriculture; p. 94.

² 'The Cruise of the *Cachalot*' (London: Smith, Elder and Co.), p. 273.

CHAPTER XXIII

THE DIGESTION OF FOOD IN HEALTH

THE object of the present chapter is to consider the bearing of some physiological facts upon such matters as the selection of foods, the arrangement of meals, and other practical questions in dietetics. It will be convenient to arrange the principal facts under separate headings.

DIGESTION IN THE MOUTH.

The mouth stage of digestion is mainly a mechanical one, and its object essentially protective. By reducing the food to a pulp, by breaking up and softening hard particles, by neutralizing or diluting irritating constituents, such as acids, and by surrounding the whole mass with a wrapping of mucus, it is sought to guard the stomach against the effects of the ingestion of injurious substances. In the accomplishment of this object thorough chewing is of the first importance, and if the food is to be thoroughly chewed it must be eaten slowly.¹ To 'bolt' the food in the manner—as it has been described—in which one posts letters interferes gravely with proper disintegration; and many a case of dyspepsia, too, is kept up, if not actually produced, by imperfections of the teeth.

At the same time, it must not be forgotten that there is a chemical side to mouth digestion as well. Starch, under the action of the ptyalin in the saliva, and by processes which need not here be described, is converted into soluble substances. The degree to which this occurs varies, partly with the form of the starch grain, and partly with the consistence of the food and the reaction of the medium.

Some forms of starch—*e.g.*, that of rye and maize—are much more readily acted upon by the saliva than others, such as potato starch; raw starch, owing to the cellulose coating of its grains, is hardly affected at all.

¹ Attention has in recent times been called to the great importance of thorough mastication by the experiments and observations of Mr. Horace Fletcher, who has proved not only how greatly very prolonged chewing facilitates digestion, but also that if the process is carried out sufficiently thoroughly the appetite and requirements of the body are satisfied by much less food than the amount usually taken. For a description of his method see a paper by Dr. Hubert Higgins ('Is Man Poltrophagic or Psomophagic?'). *Lancet*, 1905, i. 1334, 1417.

Porous foods, into which the saliva can readily penetrate, are more easily attacked than dense and compact masses of food, such as new bread. Moist substances, too, offer less resistance than those which are dry. As regards this matter Pereira has pointed out an analogy in the preparation of tinctures by percolation, the substance to be extracted being much more readily acted upon if it has been subjected to a preliminary moistening. In accordance with this, it has been found that dry bread, taken alone, is digested to a much smaller extent in the mouth than if it be eaten along with water. A natural provision is made for the larger amount of ptyalin required for the digestion of dry foods, for Pawlow found, in his experiments on dogs, that such articles caused a much greater reflex flow of saliva than moist foods did. The latter, indeed, seemed hardly to provoke any flow of saliva at all. We have here a confirmation of the view that the uses of the saliva are mainly mechanical, for the object of the increased flow is apparently to moisten the dry food, even more than to digest its starch.

In describing the influence of such articles as vinegar, malt liquors, and wines, on salivary digestion, it was pointed out how marked was the retarding effect of the acids which these fluids contain upon the action of ptyalin, and the same was found to hold good for the tannic acid in tea. It must be noted, however, that the merely chemical effect of these beverages may be to a large extent counteracted by the more profuse flow of saliva which they often induce. All sour fluids possess this property, and the warmth of tea and the bitter ingredients of beer enable them to exert a similar effect. Wines, however, do not seem to be powerful sialogogues, though some of them, *e.g.*, sherry, excite a more abundant secretion of mucus.¹

Another important use of saliva which must never be forgotten is that of washing the mouth clean from food particles, which would otherwise remain between the teeth and undergo decomposition. So important is this hygiene of the mouth in the prevention of dental caries that many dental surgeons advise that a meal should always end with raw fruit, which stimulates a flow of saliva, besides having in itself cleansing properties in virtue of its acid juices.²

DIGESTION IN THE STOMACH.

Just as the chief object of digestion in the mouth is to protect the stomach, so the chief object of digestion in the stomach is to protect the intestine. Observations of the results of complete removal of the

¹ See Aitchison Robertson, 'The Salivary Digestion of Starch in Simple and Mixed Diets,' *Journal of Anatomy and Physiology*, 1898, xxxii. 615.

² Sim Wallace, *Lancet*, i., 1915, p. 1229.

stomach in man have shown that its co-operation cannot be regarded as essential to the complete digestion and absorption of an ordinary mixed diet, provided the latter be presented to the intestine in a suitable mechanical form.¹

The chief functions of the stomach, indeed, are probably these:²

1. To act as a reservoir.
2. To reduce the food to a semi-fluid form.
3. To sterilize the food—at least in part.
4. To regulate its temperature.
5. To effect a slight degree of absorption.

We shall briefly consider each of these functions separately.

1. By acting as a **reservoir**, the stomach enables us to take our food in considerable quantities at a time; *i.e.*, it renders *meals* possible. The practical convenience of this needs no demonstration, but some other points connected with the question of meals require to be raised.

And first it may be asked, At what intervals should *meals* be taken? Is it better to take several small meals, or to consume one's daily supply of food at one or two sittings? The reply undoubtedly is that several small meals are best. The 'one-meal-a-day man' is at a double disadvantage: (1) he is apt to overburden the mechanical powers of his stomach by the mere weight of food introduced into it at one time; (2) some of the constituents of food so introduced are partly wasted, owing to the assimilative powers of the tissues being unable to keep pace with the flood of nutriment which reaches them all at once. Let us consider each of these points for a moment.

(1) The capacity of the human stomach is very variable, both in different individuals and in the same individual at different periods of life. On the average it may be put down as from 2 to 4 pints,³ and in the case of solids at about 2 pounds. If it be remembered that the total amount of solid food required daily is at least 3 pounds, it is evident that if one were to take the whole of this in one meal he would be apt to overtask the powers of the stomach, or to produce a gradual dilatation of the organ. In the case of persons of feeble digestive power the limitation of the bulk of meals is of even greater importance. For them 'little and often' is the golden rule.

(2) There is evidence to show that more food is wasted when it is all taken at once than when it is spread over a considerable time. The waste chiefly affects the proteins, which are the most rapidly

¹ Schlatter, *Lancet*, 1898, i. 141.

² An additional function is the establishment of osmotic equilibration between the blood and the fluid food. See Jona, 'The Osmotic Pressure of Liquid Foods' (*Bio-Chemical Journ.*, 1909, iv. 462).

³ See Gillespie, 'The Natural History of Digestion,' p. 274, and the same author's 'Modern Gastric Methods,' p. 3, 1899.

digested of the constituents of the food, and is partly due to defective absorption and increased opportunity for intestinal putrefaction. Ranke, for instance, found that if he ate 1,800 grammes of meat all at once the loss by the bowel amounted to 12 per cent., but if the same quantity of meat was divided into three meals the waste was only 5 per cent. The loss of protein must also be attributed in part to defective assimilation. If the tissues are so flooded with protein that they are unable to assimilate the whole of it, the excess appears to be rapidly excreted in the form of urea instead of being stored up. This, at least, was the conclusion which Krummacher¹ drew from his experiments on dogs, in which he tested the effects of giving a certain quantity of food in one meal, and then when divided into five meals. He found that more nitrogen was excreted in the former case than in the latter. It follows from this that care must be taken not only to have enough total protein in the diet, but to see that it is evenly spread over the day, so that the tissues may not at one time be repleted and at another be compelled to draw on their own reserves. The tissues, in fact, may be compared to a reservoir, the outflow from which is pretty constant, and to which, if it is to be kept full, the inflow should also be fairly steady. A practical example of the neglect of this principle is thus given by Clement Dukes (he is speaking of the unwise division of meals often observed at public schools):²

‘For instance, if bread-and-butter only be provided for breakfast, say at 8 a.m., this will be digested and used up by the system long before dinner takes place at 1.30 p.m., and therefore from about 11 a.m. to 1.30 p.m. the body will be starved. Then at dinner the boy can only eat a certain amount of food, however much the caterer may supply, and thus the defect of the two hours and a half of starvation is never recovered, although growth must take place all the same.’

The hours of meals have varied greatly even in the same country at different periods of history, and must depend largely upon convenience and upon habits as regards work, etc. If possible, dinner, the principal meal of the day, should be taken after work is over, so that comparative repose may be enjoyed after it. As a matter of actual observation, Voit found that 50 per cent. of the day's protein, 61 per cent. of its fat, and 32 per cent. of its carbohydrate, was taken at dinner.

2. The second function of the stomach is to reduce the food to a semi-fluid form. This is done partly by the solvent action of the

¹ ‘Wie beeinflusst die Vertheilung der Nahrung auf mehrere Mahlzeiten die Eiweisszersetzung?’ *Zeit. f. Biolog.*, 1897, xxxv. 481.

² ‘School Diet,’ second edition, p. 9.

gastric juice, and partly by the mechanical movements of the stomach walls. We may therefore glance for a moment at—

The Secretion of Gastric Juice.

Until recent times it was supposed by physiologists that the secretion of gastric juice was chiefly brought about by mechanical stimulation of the mucous membrane of the stomach by the particles of food introduced into it. The elaborate and ingenious experiments of Pawlow,¹ however, have shown that this is a mistake, and that the chief factors concerned in bringing about the secretion are (1) psychical and (2) chemical, and that mechanical action plays quite a secondary part, if, indeed, it comes in at all.

The psychical factor is intimately bound up with the sensations of **appetite** and **hunger**. It is difficult to define these terms exactly, though appetite may be described as the *desire* for food, and hunger as the *need* for it.² Appetite is dependent partly upon hunger—as Von Noorden has it, it is to be regarded as ‘the reflection of the Calorie-requirements of the tissues’—but partly also upon the state of the stomach and alimentary tract generally. Thus, an individual may complain of ‘hunger’ even although the stomach is full, as in those cases where a fistula exists high up in the intestine, and prevents the food from reaching the tissues;³ or the stomach may be quite empty, and yet no complaint of hunger made, as, for example, in the case of patients who are being fed per rectum. In disease of the stomach, too, or where it is in a state of functional anæsthesia, appetite may be in abeyance, although the need for food (‘tissue hunger’) exists. In such a case the introduction of food into the stomach may suddenly awaken appetite. Pawlow mentions a good example of this in his own experience. He was convalescent from a trifling illness, and in spite of some days’ abstention from food still suffered from complete loss of appetite. He then swallowed

¹ ‘Die Arbeit der Verdauungsdrüsen,’ Wiesbaden, 1898. Pawlow’s chief results have been confirmed, in the case of the human subject, by Schüle (‘In wie Weit Stimmen die Experimente von Pawlow am Hunde mit den Befunden am normalen menschlichen Magen überein?’), *Deut. Arch. f. Klin. Med.*, 1901, lxxi. lxxi.

² This probably does not cover the whole difference between appetite and hunger. The sensation of pleasure seems inseparable from the former, that of pain from the latter. Appetite is more particularly related to the stomach, and has its seat in the brain cortex. Hunger appears to be more connected with the nutritive needs of the tissues, and possibly affects more the centres which preside over organic life. There is reason, too, to believe that the sensation of hunger is peculiarly associated with a deficiency of proteins in the blood, and can only be really allayed by a supply of them in the food. Fat, on the other hand, seems to have a special power of appeasing appetite. Advantage of this fact has been taken by Oertel in his dietary for the treatment of obesity (see p. 498).

³ For a description of such a case see Busch, *Virchow's Archiv.*, 1858, xiv. 140.

a glass of wine, and immediately a strong desire for food arose. This is a case in which *l'appétit vient en mangeant*.

While, then, appetite can hardly exist without some degree of hunger, the latter may be present without the accompaniment of the former. In health, however, the two seem to co-exist, and appetite is a true index of the amount of nutriment required by the tissues. It may be that some people, otherwise healthy, have habitually less appetite than corresponds to the true needs of their tissues, and this may explain some cases of malnutrition. Von Noorden¹ is of opinion that this state of things may be brought about by defective feeding in childhood, *i.e.*, by the use of food which does not make sufficient demand upon the digestive powers, and allows the stomach and intestines to grow up in a condition of functional feebleness. Hence in after-life, when compact and highly nourishing food cannot be obtained, a more bulky diet satisfies the stomach before the needs of the tissues are really supplied. For this reason, also, such persons are often poor eaters of fat, for it is difficult to take much fat without repugnance in a mainly animal form, but comparatively easy when diluted with a large bulk of vegetable food.

This discussion has led us away somewhat from our starting-point—the relation of appetite to the secretion of gastric juice. The experiments of Pawlow, already mentioned, have shown that appetite is the most powerful excitant of gastric secretion. The mere sight or smell of food and the act of chewing are followed, if appetite be present, by a profuse flow of a peculiarly powerful gastric juice which may continue for as long as four hours. Hence the importance for digestion of such æsthetic aids to appetite as agreeable surroundings, a well-appointed table and good cooking, and the use before dinner of such ticklers of the palate as ‘sherry and bitters’ or the savoury articles usually classed on the menu as *hors d'œuvres*.²

The other factor mainly concerned in producing gastric secretion is a chemical one, the active agents being the chemical constituents of the food. The remarkable fact has recently been elicited that the stimulus so exerted is not a general, but a *specific* one, each food calling forth a supply of those ingredients of the juice specially required for its own digestion. Some easily dissolved foods, for example, such as meat, produce a flow of juice large in quantity, but poor in ferments; other foods, such as bread, which are more difficult of solution, cause a scanty but very concentrated juice to be

¹ *Berliner Klinik.*, 1893, vi., Heft 55.

² It is an important fact, however, that the human stomach appears to be capable of digesting even in the absence of all psychical influences—*e.g.*, if food be introduced into it without the subject's knowledge (see Schüle, *op. cit.*).

secreted which is very rich in ferment ; milk, again, which is one of the most easily digested of all foods, produces only a moderate amount of juice, and that of weak digestive power.

This capability of foods to bring about the secretion of a specific kind of gastric juice specially adapted to the requirements of their own digestion is of importance for this reason, that it enables 'digestive habits' to be very readily established. Let us suppose, for instance, that a patient has been confined for some time to an exclusively milk diet. His stomach soon acquires the habit of manufacturing a secretion specially adapted for the digestion of milk. But this, as we have seen, happens to be a secretion of small digestive power. If the diet be now changed to one, say, chiefly composed of bread, some time may elapse before the specific secretion specially suited to the digestion of bread is established, and meanwhile dyspepsia may result. This may explain why sudden changes of diet are to be avoided.

'If,' says Pawlow,¹ 'one alters the diet of an animal and goes on giving the new food, one finds that the ferments contained in the digestive juices accommodate themselves more and more every day to the altered diet. If, for example, one feeds a dog for some weeks on milk and bread only, and then changes to a purely meat diet, which contains much more protein and almost no starch, one observes a gradual increase in the protein ferments of the pancreatic juice. The capability of digesting protein increases day by day, whilst, conversely, the starch-digesting power falls off. This adaptation takes place much more readily in some animals than in others. Where it does not easily occur, a sudden change of diet may produce considerable digestive disturbances.'

In the light of these facts one can understand the enormous importance of establishing good 'digestive habits' in the young. If a child is encouraged to avoid fat, for example, he may ultimately lose the power of producing the secretion specially suited to the digestion of fatty foods, and may thus, with the best intentions, be unable to eat much fat all his life afterwards, and so suffer from impaired nutrition. This is the more to be regretted as there is reason to believe that inability to digest fat renders one peculiarly liable to become the victim of tuberculous diseases.

Curiously enough, it is not *all* chemical constituents of the food which are capable of exciting a secretion of gastric juice. Egg-white, for instance, produces none, nor do the albumoses, peptone, starch or sugar ; milk, gelatin, and water produce slight secretion, while the extractives of meat are amongst the most powerful excitants

¹ *Op. cit.*, p. 52.

known. Soup makes a good beginning to a meal, because it stimulates a flow of gastric juice, not only by its warmth, but also by virtue of the gelatin and extractives of meat which it contains.

On the other hand, fat seems actually to restrain the secretion of gastric juice even when other foods are present as well. This is no doubt one reason why fat things are difficult to digest, and why skim milk is 'lighter' than milk rich in cream. It teaches us also that such articles as cod-liver-oil should be given some time after meals, when the gastric juice has been already poured out.

Acidity of the Gastric Contents.

The total amount of hydrochloric acid present in the stomach depends upon the quantity of gastric juice secreted. The *proportion* of acid present in the juice is very constant in the same individual. In different persons, however, it varies from about 1 to $2\frac{1}{2}$ parts per 1,000 of juice. The cause of these individual differences is not quite clear, but they seem to depend to some extent upon the kind of food habitually taken, persons who live largely upon meat having usually a more acid juice than those who partake more freely of vegetables.¹ This is another example of the establishment of a 'digestive habit,' to which reference has already been made.

The total amount of acid present in the stomach rises gradually during the first three-fourths of the period occupied by the digestion of a meal, and then falls off rapidly during the remaining fourth. The fall in acidity is probably to be explained by the pouring out towards the end of digestion of a neutral or slightly alkaline juice from the pyloric end of the stomach.

Of the total amount of acid present in the gastric contents at any moment, only a small part exists in the free form; the larger part is in a state of combination. The hydrochloric acid first poured out is fixed by any bases which may be present in the food (*e.g.*, carbonates and lactates), and after these have been neutralized the proteins of the food lay hold of the rest of the acid and enter into organic combination with it, and it is only after these have been saturated that the acid is able to make its appearance in the stomach in a free form. The exact moment at which this occurs must obviously vary greatly with the amount of food in the stomach and the proportion of protein which it contains. The larger the meal and the richer it is in proteins, the longer will the appearance of

¹ See Verhaegen, 'Physiologie et Pathologie de la Sécrétion Gastrique,' Paris, 1898, p. 9; also Gillespie, 'The Natural History of Digestion,' p. 106. Schüle, however, found that the kind of food has very little influence on the percentage of acid in the gastric juice (*op. cit.*).

free acid in the stomach be delayed. As an illustration of this, the following observations of Penzoldt¹ may be cited :

After 7 or 8 ounces of sweetbread free acid was present in one hour.

After 7 or 8 ounces of chicken free acid was present in two hours.

After 7 or 8 ounces of beef-steak free acid was present in three hours.

After $5\frac{1}{2}$ ounces of vegetable food, free acid was usually found in one or one and a half hours ; but if the food was one very rich in protein, *e.g.*, peas or lentils, its appearance was delayed for three hours or more.

The amount of *free* acid present does not usually exceed 1 part in 1,000 of the stomach contents, and its presence persists for about one and a half hours. We must now briefly consider the relations of the acidity of the stomach (1) to the gastric digestion of starch ; (2) to morbid gastric sensations.

Digestion of Starch in the Stomach.

There is no doubt that ptyalin is rapidly killed by *free* hydrochloric acid, and even if 0·1 per cent. is present its action on starch ceases entirely. The effect of *combined* hydrochloric acid on the ferment, however, is by no means so certain, and the experiments of different authorities on the subject have yielded very discordant results,² but it seems to be generally agreed that the presence of anything like a large amount of combined acid is highly inimical to the conversion of starch. It follows from this that the digestion of starch in the stomach is not likely to continue for more than half an hour—or at most one hour—after the taking of a meal. Obviously, the process can go on longer the greater the proportion of hydrochloric acid which passes into the combined form ; in other words, the presence of a large amount of protein in the food is favourable to the digestion of starch in the stomach, whereas if the meal consists exclusively of carbohydrates the process must sooner come to an end. This is one of the many advantages of a mixed diet.

Observations with the X rays have shown further that the food last swallowed is received into the centre of the mass already present in the stomach, and does not for some time come into contact with the mucous membrane and thus with the gastric juice. The

¹ *Deut. Archiv. f. Klin. Med.*, 1894, liii. 209.

² See Gillespie, *op. cit.*, p. 157 ; Aitchison Robertson, *Edinburgh Medical Journal*, 1896, xli., part ii. 1010 ; A. E. Austin, *Boston Medical and Surgical Journal*, 1899, cxl. 325.

central portion of the contents can, therefore, retain an alkaline reaction for a considerable period, during which ptyalin can go on acting. This justifies the conventional arrangement of a dinner in which the starchy course (pudding) comes after the protein course (meat). *

*Relation of the Acidity of the Stomach Contents to Morbid
Gastric Sensations.*

In health digestion proceeds quite unconsciously and without the production of any sensation at all. In morbid conditions of the stomach, however, digestion may be accompanied by sensations of pain, and these seem to arise in at least two ways: (1) from disorder of the motor functions of the stomach; (2) from abnormal conditions of the mucous membrane.

The former of these we shall consider later. The latter seems to be of two sorts: (*a*) where the mucous membrane is unduly sensitive to the *total acidity* of the contents; (*b*) where *free* acid alone produces pain. The former of these conditions seems to be present where actual lesions of the mucous membrane exist—*e.g.*, in ulcer and in carcinoma; the latter is apparently more often of the nature of a neurosis—a hyperæsthesia of the nerves of the mucous membrane, though it is possible that in extreme degrees of such hyperæsthesia pain may be produced even by combined acid. Where the total acidity causes pain the condition is likely to be aggravated by foods rich in protein, such as meat, for these, as we have seen, call forth an abundance of juice, and therefore of acid. If, on the other hand, free acidity alone excites the sensation, such foods are likely to be beneficial, for they delay the period at which free acid appears, and also lessen its amount. In accordance with this explanation, I think it will be found that patients who are suffering from ulceration of the stomach complain of pain after meat, but can digest milk with comfort; for milk not only neutralizes much acid by means of its bases, but in itself calls out the secretion of a weak and scanty gastric juice. On the other hand, one usually finds that patients with functional dyspepsia and hyperæsthesia of the stomach suffer less from meat than from foods which, being poor in proteins, allow of the early appearance of uncombined hydrochloric acid. These considerations are of importance in helping one to select a suitable dietary for dyspeptics.

Movements of the Stomach.

In studying the movements of the stomach, one must distinguish quite sharply between the cardiac and the pyloric end of the organ. There is no doubt that this distinction is not grasped as clearly as it ought to be. The two ends are distinct, both anatomically and functionally. The cardiac end secretes both pepsin and hydrochloric acid, the pyloric end pepsin alone. The former has but feeble motor power; the movements of the latter are frequent and powerful. This functional difference would be found, I think, to explain to some extent the respective liability of the two ends to different diseases, but that subject cannot be entered upon here.

Nor is it commonly recognised that the two portions of the stomach are separated from each other by a thickening of the muscular coat—the transverse band—which acts as a kind of ‘pre-pyloric sphincter.’ The existence of this sphincter was long ago pointed out by Retzius.¹ It is situated at a variable distance from the pylorus, and, though it cannot always be demonstrated in the cadaver, it is probably always present in the living organ. Thanks to the existence of this sphincter, the stomach is able to ‘sort’ its contents into those which are in a fit state to be passed on into the intestine, and those which must be kept back to be further acted upon by the gastric juice. The sorting is probably brought about in this way: Shortly after the food enters the stomach feeble peristaltic waves are set up in the cardiac end, which keep up a slow revolution of the contents, sufficient to ensure their complete mixing with the gastric juice, but not of sufficient strength to exercise any real pressure on the food masses such as might break them up mechanically. These waves seem to stop at the transverse band, their point of cessation being marked in the living stomach by the appearance of a sulcus. They are strong enough to squeeze the fluid part of the contents past this constriction on into the pyloric end, but are not sufficiently powerful to do the same for solid, undigested lumps. In this way the digested parts of the food are separated from the rest. The movements of the pyloric end are, as has already been mentioned, much more active than those of the fundus. It is here that the food is mixed with the gastric juice, rubbed down into a more or less fluid consistency and expelled into the duodenum. The mechanism by which this takes place is as follows (Cannon):

¹ *Muller's Archiv.*, 1857, p. 74. He describes the transverse band as the ‘sphincter antri pylori.’

Whilst food is present in the stomach constriction waves are seen continually coursing over the antrum towards the pylorus. The fundus meanwhile serves as an active reservoir for the food, and squeezes out its contents gradually into the pyloric portion. The stomach is emptied by the formation, between the fundus and antrum, of a tube along which constrictions pass at regular intervals of fifteen to twenty seconds. The contents of the fundus are pressed into the tube, and the tube and antrum slowly cleared of food by the waves of constriction. The food in the pyloric portion is first pushed forward by the running wave, and then by pressure of the stomach wall is returned backwards through the ring of constriction, being thus thoroughly mixed with gastric juice. Finally, when the solid food has been thoroughly triturated by the constrictions, the pylorus opens and allows the contents of the antrum to escape.

The activity of the peristaltic movements of the stomach seems to depend in part on the temperature of the contents, and in part on their chemical nature. Mere mechanical contact seems to have but little stimulating effect upon them. Hot food increases the frequency and vigour of the movements, and so does a highly acid condition of the contents. It may be for this reason that the movements become more vigorous as digestion proceeds. Such stimulating substances as mustard, alcohol and carbonic acid gas seem to have a similar effect.

The length of time which elapses between the swallowing of food and the first opening of the pylorus is variable, depending chiefly upon the consistence of the food and the temperature and reaction of the stomach contents. Fluids, unless they contain much solid matter in solution, begin to escape almost immediately, water, indeed, whilst it is still being swallowed.

Any excess of fluid taken with a solid meal is probably also passed on almost at once, and so cannot seriously dilute the gastric juice. Solid food can only escape after it has been reduced to a fluid or semi-fluid consistency, and this must obviously depend to a large extent upon its physical characters and density.

Busch, in his observations upon a patient with a duodenal fistula, saw the escape of food after as short an interval as fifteen or thirty minutes.¹

The larger part of a meal, however, probably does not pass out of the stomach till most of it has been completely digested, and half an hour after that has taken place the stomach may be regarded as empty.

¹ *Virchow's Archiv.*, 1858, xiv. 140.

Warmth tends to accelerate the opening of the pylorus, but a very acid condition of the stomach contents has a contrary effect. Organic acids have perhaps a more powerful influence in this direction than hydrochloric acid, and may induce an actual spasm of the orifice. A dose of alkali may relieve the pain which such spasm causes. Hence it is only towards the close of digestion, when the acidity of the stomach contents has been reduced by the addition of the neutral or slightly alkaline secretion of the pyloric end, that the conditions most favourable to the escape of food come into existence. It has been found, also, that the duodenum exercises a controlling influence over the pylorus, distension of it inhibiting the opening which would otherwise take place.

Rate of Digestion of Different Foods.

Seeing that food cannot be passed on into the intestine until it has been brought into a state of solution, it is obvious that we have, in the period which elapses before the stomach is empty after the taking of any particular article of diet, a criterion of its digestibility as far as the stomach is concerned. In previous chapters the relative digestibility of different foods has been considered in detail, but it may be well at this point to summarize our knowledge of the subject.

Most of our information on this matter has been derived from the experiments of Penzoldt on healthy men.¹ He found, as might have been expected, that the amount and consistency of the food have a strong determining influence in the rate of digestion. Fluids escape most rapidly of all. Thus, 7 ounces (200 c.c.) of water have entirely left the stomach in one and a half hours,² and tea, coffee, and alcoholic liquors in the same time. Hot drinks, contrary to what might have been expected, did not seem to leave sooner than cold, nor did the *quantity* of fluid make much difference, so that it scarcely matters, as regards stay in the stomach, whether one takes 3 or 6 ounces of fluid. On the other hand, the presence of solid matter in solution or suspension in the fluid caused it to remain longer, but not much, 7 ounces of boiled milk staying about two hours. Meat-juices, and water containing in solution such substances as peptone, did not remain any longer than ordinary water or milk. Aerated water was found to remain in the stomach for an even shorter time than plain

¹ *Deut. Archiv. f. Klin. Med.*, 1893, li. 535. The experiments of Beaumont are of very little value, owing to the fact that they take no account of the amount of food given.

² The time was always calculated from the moment at which the food had begun to be swallowed.

water, probably because the carbonic acid which it contains accelerates the stomach movements.

As regards solids, digestibility is influenced much more by consistence than by amount.¹ An increase in the quantity taken prolongs, it is true, the duration of stay in the stomach, but not proportionally. Doubling the amount eaten, for instance, does not mean doubling the length of time required for digestion. In the case of meat, to take an example, an addition of 50 grammes caused only an increase of one hour in the time required for complete digestion, and in the case of biscuits a similar addition produced an extra delay in the stomach of only seventy minutes. Put otherwise, six times the original quantity of beef requires only three times the original amount of time taken by digestion; in the case of biscuits, four times the original quantity requires double the time, while with fluids the original quantity can be increased five times while only doubling the original time.

The chemical composition of the food, also, is of importance. Carbohydrates, proteins, and fats do not leave the stomach at the same rate. Carbohydrates begin to leave the stomach within ten minutes of their ingestion; they pass out rapidly, and at the end of two hours reach a maximum amount in the small intestine. Fats, on the other hand, remain a long time in the stomach. Their discharge into the small intestine begins slowly, and continues at about the same rate as their absorption or their passage onwards into the large bowel. Proteins remain an even longer time, and their rate of discharge is slower than that of fats.

Of animal foods, the most rapidly digested were those of a soft consistence, such as sweetbread. The white meats, *e.g.*, chicken, were more digestible than dark, *e.g.*, duck, or even the red meats, but the method of cooking had great influence on the result. Fresh fish, in his experiments, was more rapidly digested than meat.

As regards vegetable foods, the consistency and the amount of solid matter contained were again the ruling factors. Thus, 'mealy' potatoes were more rapidly disposed of than 'waxy,' and in purée more easily than when in pieces. Fine bread and biscuits were found to be more digestible than coarse bread, but there was not much difference between crust, crumb and toast, or even between new and stale bread, provided all were equally well chewed. Cauliflower was the most rapidly digested of vegetables.

The following table contains a summary of these results in greater detail, along with the fuel value of the quantity of each article employed:

¹ See Lehmann, 'Ueber die Bedeutung der Zerkleinerung und des Kochens der Speisen f. die Verdauung,' *Arch. f. Hygiene*, 1902, xliii. 123.

TABLE SHOWING RATE OF DIGESTION OF DIFFERENT FOODS AND THEIR CALORIE VALUE.¹

LEAVE STOMACH IN 2 TO 3 HOURS.

Food.	Calories in Form of			Total Calorie Value.
	Protein.	Carbohydrates.	Fat.	
400 c.c. (14½ ounces) boiled milk ..	57·4	78·8	137·6	273·8
100 grammes egg, raw, poached, or omelette (=about two eggs)	51·7	2·1	112·5	166·3
100 grammes beef sausage (3½ ounces) ..	59·7	—	372·0	431·7
200 „ sweetbread (7 ounces)	229·6	—	0·4	230·0
72 „ oysters (10 of moderate size) ..	17·7	10·7	7·7	35·1
200 „ white fish (7 ounces)	179·6	—	20·5	200·1
200 „ shell-fish	139·4	—	9·3	148·7
150 „ asparagus (5½ ounces)	12·3	12·3	—	24·6
100 „ white bread (3½ ounces or 1½ slices)	23·7	213·2	4·6	246·5
100 grammes rusks.. ..	35·3	307·9	9·3	352·5
50 „ biscuit (1½ ounces).. ..	21·4	150·0	21·4	192·8

LEAVE STOMACH IN 3 TO 4 HOURS.

Food.	Calories in Form of			Total Calorie Value.
	Protein.	Carbohydrates.	Fat.	
230 grammes chicken (8½ ounces) ..	188·6	—	85·6	274·2
250 „ lean beef (9 ounces)	215·2	—	34·8	250·1
160 „ boiled ham (6 ounces)	157·4	—	535·7	693·1
100 „ roast veal (3½ ounces)	82·0	—	13·9	95·9
100 „ beefsteak „	140·3	—	76·4	216·7
100 „ salted caviare (3½ ounces) ..	127·1	—	148·8	275·9
150 „ coarse bread (5½ ounces) ..	36·9	307·5	6·9	351·3
150 „ boiled rice „	18·5	467·4	—	485·9
150 „ boiled cabbage (5½ ounces) ..	18·5	49·2	—	67·7

LEAVE STOMACH IN 4 TO 5 HOURS.

Food.	Calories in Form of			Total Calorie Value.
	Protein.	Carbohydrates.	Fat.	
250 grammes smoked tongue (9 ounces)..	247·0	—	721	96·8
100 „ smoked beef (3½ ounces) ..	110·7	—	139·5	250·2
250 „ roast goose (9 ounces)	164·0	—	106·0	122·4
200 „ salt herring (7 ounces)	154·9	12·3	314·3	481·5
150 „ lentil porridge (5½ ounces) ..	153·7	332·1	—	485·8
200 „ pease porridge (7 ounces).. ..	188·6	426·4	—	615·0

One may compare with these observations those of Verhaegen,² who concludes from a large number of experiments that—

½ litre boiled milk leaves the stomach in 2½ hours
 100 grammes of bread leave the stomach in 3 „
 150 „ „ „ and 60 of meat leave the stomach in 4 hours.
 An ordinary dinner leaves the stomach in 4 to 5 hours.

¹ Modified from Strauss, *Zeit. f. Diät. Therapie*, 1900, iii. 198, 279, and based on the results of Penzoldt (*Deut. Archiv. f. Klin. Med.*, 1893, li. 535).

² 'Physiologie et Pathologie de la Sécrétion Gastrique,' Paris, 1898.

Leube¹ divides foods into four groups, according to the ease with which they are digested, the first group containing those which are most digestible :

1. Beef-tea, solution of meat (Leube-Rosenthal), milk, soft or raw eggs, Albert biscuits.
2. Boiled calves' brains, sweetbread, boiled fowl, pigeon or calves, feet.
3. Scraped underdone steak, potato purée, stale bread.
4. Roast chicken or pigeon, roast veal, cold roast beef (underdone), white fish, macaroni, rice, chopped spinach.

A study of all these results will enable one to select the most suitable foods for persons of weak digestion.

3. Antiseptic Action of the Gastric Juice.—Another function which the stomach serves is that of partially sterilizing the food by the antiseptic action of the hydrochloric acid of the gastric juice. This action, however, is not a powerful one, and some organisms, such as those that form acids, seem to escape it altogether, and there is reason to believe that the same is true of some, at least, of the commoner pathogenic organisms, notably the tubercle bacillus.

The sterilizing power of the stomach must vary greatly according to the period of digestion and the nature of the food. It probably reaches its maximum towards the later periods of digestion, when hydrochloric acid is present in the free state, whilst it is much less, or even absent altogether, in the earlier stages, when all the hydrochloric acid is in a combined form. Food rich in protein, by fixing the hydrochloric acid, must greatly lessen the germicidal power of the gastric juice. Over the growth of organisms in the intestine the stomach seems powerless to exert any control. Even in cases in which the secretion of hydrochloric acid is entirely arrested, or in which the stomach has been completely removed, no increase in the amount of intestinal putrefaction was found to occur.²

4. The Temperature of Foods and Drinks.³—One of the minor functions of the stomach is that of regulating the temperature of the food. It stands in this matter as a protector of the intestine, which appears to be more injuriously affected by extremes of temperature than the stomach itself.

The ideal temperature for food is probably that of the body itself.

¹ *Zeit. f. Klin. Med.*, 1883, vi. 189.

² See Schlatter, *Lancet*, 1898, i. 141, and Filippi, *Deut. Med. Wochens.*, 1894, xx. 780.

³ See Späth, *Archiv. f. Hygiene*, 1886, iv. 68, and Uffelmann, *Wiener Klinik*, 1887, xiii., Heft 9.

Cold food is difficult to digest, for it does not excite the stomach sufficiently, nor does it possess the stimulating properties of a hot meal. It has been observed that there is a special craving for alcoholic stimulants on the part of those who are unable to get hot meals.

Extremes of temperature in foods should be avoided as tending to produce local injury to the stomach; from 45° to 130° F. are probably the limits of safety.

Drinks at a temperature of 122° F. are sufficient to warm the body, and a temperature of 45° F. is sufficient to cool it. Wunderlich¹ found that hot punch at 122° F. raised the temperature of the body by 0·1° to 0·3° C. for a period of thirty to sixty minutes, while half a litre of water at the same degree of heat caused an acceleration of the pulse by nearly 20 beats per minute very shortly after it had been swallowed.

On the other hand, three tumblerfuls of water at a temperature of 45° F. produced a lowering of the axillary temperature from 98·4° F. to 97·7° F., while the pulse-rate fell from 70 to 61 per minute.

Violent alternations in the temperature of foods seem to cause fissuring of the enamel of the teeth. Uffelmann, for instance, placed recently-extracted teeth in water first at 65° C., and then directly afterwards at 6° C., and in nine out of eleven cases he produced some degree of splitting of the enamel.

The local effects of extremes of temperature in the stomach are very much the same whether the extreme be one of heat or of cold. In each case there is a danger of exciting gastric catarrh. Very hot foods seem to be specially dangerous in stomach-bleedings, *e.g.*, ulcer; and there are some who say that the special liability of cooks to suffer from gastric ulcer is to be attributed to their constantly tasting very hot foods. On the other hand, very warm fluids may relieve pain in the stomach by abolishing pyloric spasm.

The temperature most suited for drinks intended to quench thirst is one of from 50° to 70° F. Ices should be avoided, as they may cause dyspepsia, cardialgia, and even acute dilatation of the stomach, although small quantities of ice undoubtedly tend to allay gastric irritability. It must also be remembered that the drinking of very cold water when one is heated may bring about a reflex congestion of the lungs.

5. **Absorptive Power of the Stomach.**—The absorptive power of the stomach is surprisingly small. In this also one may see

¹ Quoted by Uffelmann.

a provision for the protection of the body, for it allows of the neutralization or rejection of injurious substances before they have time to enter the blood. Alcohol, curiously enough, is of all substances that which the stomach absorbs most readily. This explains to some extent the rapid stimulating action of alcohol. Peptone, sugars and salts, are also absorbed by the stomach to some extent. The stronger the alcohol, or the more concentrated the solution of these substances, the greater is the degree of absorption.

There is reason to believe that the process of absorption by the stomach is much more of the nature of a mere physical osmosis than is the case in the intestine, and the process is accompanied by the pouring out of a good deal of secretion. It is in this way, perhaps, that a mixture of alcohol and sugar, such as is found in sweet wines and some malt liquors, may cause 'acidity.' The practical bearings of absorption in the stomach will be more fully dealt with, however, when we come to consider the dietetic treatment of gastric dilatation.

DIGESTION AND ABSORPTION IN THE INTESTINE.

When the food has passed through the pylorus, it enters the duodenum and encounters the secretion of the pancreas. The anatomical disposition of the duodenum seems specially designed to favour complete mixing of the chyme with the pancreatic juice, for the duodenal loop forms a kind of U-tube, in which some delay of the contents may be expected to take place. The degree of distension of this loop seems to have some influence, too, over the opening of the pylorus, so that as long as the duodenum is full no further escape of food from the stomach takes place.

The chief stimulant of the pancreatic secretion is the hydrochloric acid, which reaches it from the stomach; the psychical factor, though active, is not nearly so potent as in the case of gastric secretion. The chemical constituents of the food also have an influence, just as they have in the case of the stomach, fat especially calling forth an abundant secretion. As the pancreatic juice is the chief agent concerned in the digestion of fat, we see in this again a wonderful adaptation of means to ends. Starch, on the other hand, has no great effect beyond that of producing a slight increase in the amount of the sugar-forming ferment.

Of the disorders of pancreatic digestion we know but little, though they are probably of less importance than those of the stomach, for the reserve power of the pancreas seems to be so great that it is quite

equal to digesting the whole of the food itself should the stomach be unable to perform its share in the process. The importance of this for dyspeptics is very great.

As the food passes along the intestine absorption of its ingredients takes place, and the degree to which this occurs in different foods has already been fully considered (p. 10.)

The influence of each constituent of the food on the absorption of others is probably of considerable importance, though not much is known about it. The addition of starch to protein, for example, diminishes the absorption of the latter, whilst fat starvation tends to lessen the absorption of phosphoric acid.¹ On the other hand, if fat is not being well absorbed, as, for example, in cases where the bile cannot enter the duodenum, the destruction of proteins by putrefaction is greatly increased, owing to the unabsorbed fat enclosing the particles of protein and interfering with their proper digestion. This furnishes an additional reason for interdicting fat in jaundice. The increase of intestinal putrefaction brought about in this indirect way no doubt led to the erroneous idea that bile is an antiseptic. Seeing that the influence of the carbohydrates is rather to retard the putrefaction of proteins, it is obvious that fats cannot replace the former as far as the intestine is concerned.²

The rôle of bacteria in intestinal digestion has sometimes been minimized, at others exaggerated. There is no doubt that they are not indispensable to digestion. On the other hand, they play a useful part in restraining putrefaction. The only bacteria which flourish in the small intestine are those which are capable of forming acids (*e.g.*, acetic, lactic, and succinic) out of carbohydrates. The acids so produced tend constantly to be neutralized by the alkaline secretion of the intestinal mucous membrane, but in the struggle which thus takes place the acids always maintain the upper hand, and consequently the contents of the small intestine have an acid reaction throughout. Thanks to this slight degree of acidity, the growth of putrefactive organisms is restrained, and the destruction of proteins especially prevented. Hence, if one wishes to diminish intestinal putrefaction, the diet must contain plenty of carbohydrates, for it is only out of these that acids can be produced, and but little protein.³ This explains the very fœtid nature of the stools passed

¹ *Journal of Experimental Medicine*, 1898, iii. 293.

² See Laas, 'Ueber den Einfluss der Fette auf die Ausnutzung der Eiweisstoffe,' *Zeit. f. Physiolog. Chem.*, 1894, xx. 233.

³ See Backman, 'Ein Beitrag zur Kenntniss der Darmfäulniss bei Verschiedenen Diätformen unter physiologischen Verhältnissen,' *Zeit. f. Klin. Med.*, 1902, xliv. 458.

by patients who are being fed exclusively on lean meat. It may be well also to remind the reader again at this point of the value of milk as an intestinal antiseptic (see p. 126).

It is important to remember that the contents of the small intestine remain fluid throughout its entire length. Even at the lower end of the ileum the amount of solid matter is only 5 to 10 per cent. The advantages of a fluid diet in intestinal ulceration, therefore, can scarcely be due to any less degree of mechanical irritation on the part of fluid food.

In the large intestine the contents of the bowel are brought to a solid form, mainly by the absorption of water. The absorptive power of the large intestine for the nutritive constituents of the food will be considered in another chapter.

The investigation of Prausnitz¹ has shown that the fæces are to be regarded as chiefly composed of the remains of the digestive juices, and that their composition is very uniform, the chief ingredients (in the dried form) being

Nitrogen	..	..	..	8 to 9 per cent.
Ether extract	..	..	..	12 to 18 "
Mineral matter	..	..	..	12 to 15 "

The fæces of a mixed diet always contain muscle fibres, but starch is completely absorbed unless pulses or green vegetables are largely eaten.

If the diet is of such a nature that much cellulose and some starch are excreted, the percentage of nitrogen falls. If, on the contrary, the absorption of nitrogen is deficient, the percentage of that ingredient rises. Other things being equal, therefore, a low percentage of nitrogen in the fæces indicates bad general absorption of the food, while a high proportion of nitrogen has a contrary significance.

The bulky fæces of a vegetable diet are largely due to the presence of an excess of moisture, which has been poured out by the walls of the bowel in the attempt to neutralize organic acids produced by fermentation.

In the large intestine, the putrefactive bacteria are able to flourish, for the absorption of carbohydrates higher up renders the further production of acids which restrain putrefaction impossible.

The following summary of the digestion of a mixed meal may serve to gather up a number of the scattered facts which have been mentioned in the preceding paragraphs:

The complex sensation called 'hunger' impels one to seek food.

¹ *Zeit. f. Biologie*, 1897, xxxv. 287.

The sight and smell of the food awakens the sensation of 'appetite,' and with it there begins a flow of digestive juices, most marked in the case of the stomach. The soup, which usually forms the first course, by virtue of its warmth and of the gelatin and extractives which it contains, accelerates and increases the secretion of the gastric juice. The solid part of the food is reduced to a pulp in the mouth, and, unless acid substances are mixed with it, part of its starch is changed into sugar. Arrived in the stomach, it encounters the 'psychical' juice already secreted, the acid of which is immediately laid hold of by the proteins of the food. In this way the acidity of the stomach contents is kept down, and the action of the saliva upon the starch is allowed to continue. As the solids become dissolved by the 'psychical' juice, their chemical constituents are set free, and themselves begin to excite a specific secretion specially fitted for their own digestion.

Meanwhile, the acidity of the contents goes on increasing, and soon brings to an end any further action of the saliva upon starch, and kills or paralyzes many of the organisms swallowed with the food, while at the same time the peristaltic movements of the stomach are excited. Under the influence of these the gastric juice and the food are intimately mixed, and the temperature of the mass gradually adjusted to that of the body. As solution proceeds, the semi-fluid part of the contents along with any excess of fluid which has been swallowed finds its way into the pyloric end of the stomach, and by the systolic contractions of the latter is propelled into the duodenum. This process continues for about four or five hours, by the end of which time the stomach is again empty. During all this time the absorption of alcohol and small quantities of peptone, sugar, and salts has been taking place.

Arrived in the duodenum, the food encounters the secretion of the pancreas already called out by psychical influences, and now increased by the stimulus of the acidity of the stomach contents and by the specific chemical action of the constituents of the chyme, especially by that of fat. Here digestion is completed, and as the food sweeps along the small intestine its constituents are rapidly absorbed into the blood, or chyle. During this time certain bacteria, which have escaped the action of the gastric juice, are busy breaking up any carbohydrates which may be present, producing from them organic acids, which restrain the putrefaction of the protein constituents of the food which would otherwise be apt to occur. The fluid poured out by the glands of the small intestine in the attempt to neutralize these acids more than makes up for any absorption of

water, and causes the contents of the ileum to remain fluid until the large intestine is reached. Beyond this point the production of acids ceases, and the rapid absorption of water causes the contents to assume a solid form, while putrefactive bacteria are able to grow unchecked, save by the products of their own activity. Finally the residue is expelled in the form of fæces, usually about twenty-four hours after the food was first swallowed.

The respective influence of exercise and rest on the processes of digestion is disputed. Beaumont, from his observations on St. Martin, came to the conclusion that *gentle* exercise aided digestion, but the experiments of Fleischer¹ gave a contrary result. The whole question is probably one of blood-supply. Gentle exercise, by increasing the rapidity of the circulation, may aid the secretion of digestive juices and stimulate the movements of the stomach. Severe exercise, on the other hand, by diverting much blood and nervous energy to the muscles, may be expected to have an adverse effect. Sleep is only useful as an aid to digestion in the case of invalids and aged persons, but even in them it may be injurious, probably on account of the depression of the circulation by which it is accompanied.

On the whole one can agree with King Chambers, that the best employment after a heavy meal is 'frivolous conversation,' which keeps the heart active without making great demands upon the brain.

¹ *Berlin. Klin. Wochensch.*, 1882, xix. 97.

CHAPTER XXIV

THE PRINCIPLES OF FEEDING IN INFANCY AND
CHILDHOOD: HUMAN MILKI. PHYSIOLOGICAL REQUIREMENTS IN THE DIET OF
INFANCY.

A HEALTHY infant spends most of its time in sleeping and growing. Its muscular efforts are confined to a little sucking, more or less crying, and some kicking. Hence it follows that the diet of an infant should contain relatively more of the tissue-builders (proteins and mineral matters), and relatively less of the energy-producers (carbohydrates), than one finds in the food of the adult. Like all small animals, too, the infant has a large extent of surface in proportion to its bulk; thus it tends to lose heat rapidly, and requires an abundant supply of the chief body fuel—fat. If these different ingredients be not supplied in due proportion, disorder of health inevitably follows. If the tissue-builders be not sufficiently represented, the muscles, blood, and bones are not properly formed, and the child becomes flabby, pale, and rickety. On the other hand, if the supply of protein be in excess of the child's digestive and assimilative powers, it suffers from disorder of the stomach and bowels. If it be an infant, curdy stools will be passed, and there will be a tendency to diarrhoea. Older children will suffer from indigestion, irritability, and restlessness. A sufficient supply of fat is of even greater importance. Indeed, it may be said that **abundance of fat** should be the main characteristic of the diet of infancy, just as abundance of carbohydrates is the chief feature of the diet of adult and laborious life. The fat serves as fuel. Without it the child has difficulty in maintaining the proper temperature of its body, and is liable to catarrhs of the lung or bowel. In addition to this great use, fat seems, during the period of rapid growth, to be itself a

tissue-producer. The infant is laying down a considerable amount of tissue rich in fat in the marrow of its bones and in its nervous apparatus, and it may well be that the fat of the diet aids in the production of such tissues. Of this, at any rate, there can be no doubt—that a child whose diet is deficient in fat rapidly loses vigour and is extremely prone to suffer from rickets. Whether this is due to a want of fat as such, or to a deficient supply of the fat-soluble (growth) vitamin, or to both of these causes, is still under discussion.

Important though an abundant supply of fat is, one must take care not to give it in excess, for under these circumstances it is a frequent cause of vomiting and diarrhoea. A milk which contains more than $6\frac{1}{2}$ per cent. of fat may always be expected to produce these results.

Carbohydrates are, as we have seen, not of so much importance in the dietary of infancy as in that of older children or the adult. They are important, however, not only as making provision for what muscular effort the child does display, but also in their capacity as protein-sparers (p. 22). If there be a due supply of sugar in the diet, it is reasonable to suppose that less protein will suffice. The carbohydrates, however, are the ingredient of the diet which is least likely to be represented in too small amount. On the contrary, there is a much greater danger of supplying them in excess, or of making them a substitute for fat. An infant which is the victim of such an error may be plump enough, but its muscles are flabby, its skin pale, and its bones often rickety. It is the false appearance of good nutrition which such infants often possess that is apt to deceive the uninitiated, and such children have been known to receive prizes at baby-shows, when all the time they were undoubtedly the subjects of rickets. It must be remembered, too, that carbohydrates, especially when given in excess and in unsuitable forms, such as starch or cane-sugar, are very prone to undergo fermentation in the stomach and intestine of the infant, whereby acids are produced and griping and diarrhoea result.

The **mineral ingredients** of the food in infancy are equal in importance to the proteins. Like these, they are concerned in building up the child's body, and deficiency of them will produce much the same symptoms as deficiency of proteins. Salts of lime, potash, and phosphoric acid are specially important. Phosphate of lime is wanted for the bones, and phosphate of potash for the muscles and blood. It must not be supposed that it is a matter

of indifference in what form these are supplied. It would seem that these salts are of much greater use when they enter the body in combination with organic matter than they are in a free mineral form. Milk, and especially human milk, is peculiarly rich in organic combinations of these salts, and for this reason lime-water or chemical preparations of salts can be no proper substitute for it. On the other hand, there is no reason to believe that the presence of an excessive quantity of mineral matter in the food of an infant does any harm; the child simply does not absorb or assimilate more of each compound than it requires for building or other purposes.

The importance of water to the infant will be evident when one recollects that more than three-fourths of the whole body consists of it, and that it constitutes about four-fifths of milk, which is the natural diet of infancy. Water has also local uses in the stomach and bowels, promoting as it does the processes of absorption and secretion. One is too apt to forget that an infant may suffer from thirst as well as from hunger, and that water will allay the former better than milk. The effect of a drink of cold water is certainly always worth trying if a child is suffering from evident but unexplained discomfort.

2. HUMAN MILK: ITS COMPOSITION AND VARIATIONS.

We have spoken on the one hand of the importance of a due supply of each nutritive ingredient in the diet of the infant, and on the other of the danger to health which results if any one of them be present in excess. One naturally turns to human milk, the natural food of infants, for guidance as to the proper quantity of each ingredient to be supplied, and for this reason the study of its exact chemical composition is of the first importance. On surveying the records of the chemical analyses¹ of human milk which have been made, one is struck both by the enormous amount of work which has been done on the subject, and at the same time by the discrepancies in the results of different observers. These discrepancies are to be explained partly by technical difficulties in milk analysis, and partly by the fact that the milk of one woman may differ not only from that of another, but may also show variations from day to day and at different periods of nursing.²

¹ For a review of analyses of human milk, see Blauberg, 'Experimentelle und Kritische Studien über Säuglingsfäces,' Berlin, 1897, and Hauser, *Fortschr. der Med.*, 1897, xv. 929.

² Konrad Gregor (Volkmann's *Samml.*, 1901, M. 88, N. F., No. 302) finds that the fat is a particularly variable ingredient of human milk, the amount of it fluctuating from day to day and from hour to hour. This shows the futility of basing conclusions upon the result of the examination of a single sample of milk.

The following¹ represents the results of analyses of human milk, taken about the middle of the second week of nursing :

Specific gravity	..	1032		Milk-sugar	..	..	6.26 per cent.
Water	..	..	87.75 per cent.	Mineral matter	..	..	0.27 "
Solids	..	..	12.25 "	Citric acid	..	..	0.05 "
Protein	..	..	1.62 "	Unknown extractives	..	..	0.91 "
Fat	..	..	3.14 "	Reaction	..	..	Alkaline.

A healthy woman produces 700 to 2,000 grammes ($1\frac{1}{2}$ to 4 pints) of such milk daily, although the former figure would be much nearer the average than the latter.

I should like to direct special attention to two points in the above analysis: First, to the small amount of protein which human milk contains, and, secondly, to the presence of a considerable proportion of 'extractive' matters. These are admittedly of unknown nature, but they contain nitrogen.² The earlier analysts classed them amongst the proteins, and hence overstated the amount of the latter which human milk contains. Furthermore, the above analysis must only be taken as representing the average composition of human milk. Considerable variations are met with, the causes of which may be considered under the following heads:

1. *Variations dependent on the Period of Suckling.*—One might naturally expect that an infant a few days old would not require the different ingredients of milk in exactly the same relative proportions as one of some weeks, and chemical analysis of milk at different periods of lactation verifies the expectation.

The milk secreted during the first two or three days after the birth of the child is called *colostrum*, and has some peculiar characters. It is more watery-looking than ordinary milk, and contains a special form of protein, which causes it to clot on boiling for the first day or two. The actual amount of protein which it contains is greater than in ordinary milk, though the exact figures given by different analysts vary on the point, some placing the amount of protein as high as 8 per cent. The following table contains the average of a number of samples of colostrum analyzed by Woodward:³

¹ Analysis by Camerer and Söldner, *Zeit. f. Biolog.*, 1896, xxxiii. 535.

² According to Rietschel (Abst. in *Maly's Jahrbuch Thier-Chemie*, 1906, xxxvi. 259), about 80 per cent. of the non-protein nitrogen of human milk is contained in urea, the rest being present in peptides and peptoids.

³ *Journal of Experimental Medicine*, 1897, ii. 217.

Specific gravity 1024 to 1034	Protein 1.9 per cent.
(variations due to differences in the	Fat 4.0 "
amount of fat)	Sugar 6.5 "
Water 87.5 per cent.	Mineral matter .. 0.2 "

Colostrum may contain a number of peculiar microscopic cells called colostrum corpuscles, the number of which is very variable. As they consist of protein, they must be of some nutritive value to the child. One of the uses of colostrum appears to be as a laxative, causing the expulsion from the intestine of the child of a quantity of waste matter with which it comes into the world.

After the third day the ordinary milk begins to be produced, and the changes which it undergoes in composition from this period onwards are exhibited in the following table:

INFLUENCE OF PERIOD OF LACTATION ON COMPOSITION OF HUMAN MILK.¹

Period.	Total N.	Protein.	Fat.	Sugar.	Ash.	Increase in Child's Weight per Day.
5th day	0.33	2.0	2.8	5.4	0.34	35 to 40 grammes
8th to 11th day	0.27	1.6	3.1	6.2	0.27	
20th ,, 40th ,,	0.20	1.1	3.8	6.4	0.22	
70th ,, 120th ,,	0.17	1.0	2.9	6.7	0.20	22 "
170th and after	0.14	0.8	2.6	6.8	0.19	18 "

A study of it will show that on the whole the building material (protein and mineral matter) tends to become less in amount as lactation proceeds, the sugar rises rapidly up to the end of the second week, and after that more slowly, while the fat, after reaching a maximum about the second month, tends to fall off again in the later periods.

A little consideration will show that these variations are very much what one would expect from the physiological requirements of the infant at different ages. During the first few weeks of life the child grows much faster than subsequently. The last column of the table shows that in the first month from 35 to 40 grammes are added to the weight each day, while by the time the sixth month is reached the daily increase in weight has fallen to 18 grammes. Obviously, then, the infant will require relatively more building material at the former period than at the latter. The gradual increase in the proportion of carbohydrate is also just what one would expect in view of the daily increasing muscular activity of the child.

A general consideration of the table clearly shows that the milk of

¹ From analyses by Camerer and Söldner, *Zeit. f. Biolog.*, 1896, xxxiii. 43, 535; increases in weight from Pröscher, *Zeit. f. Physiolog. Chem.*, 1897, xxiv. 285. Reyher, however (Abst. in *Maly's Jahrbuch Thier-Chemie*, 1906, xxxv. 308), took mixed samples of the milk before and after nursing, and found that between the 115th and 187th days it contained from 4.28 to 4.98 per cent. of fat, whilst between the 208th and 225th days, when secretion began to fail, the percentage was from 4.9 to 5.98.

the mother certainly does not get richer as the child gets older, but that the increasing demand for nutriment by the growing infant is met by supplying an increased quantity of milk, and not by providing an improved quality.

This fact should be noted by those who have to provide artificial substitutes for human milk. It follows, also, that there is some scientific justification for the popular view that a wet-nurse should not suckle a child which is much younger than her own. The difference, however, between the composition of milk at the third week and third month is not sufficiently great to make such a difference between the ages of the two infants a bar to the employment of the nurse.¹

2. *Variations dependent on Individual Differences in the Mother or her Child.*—These are of comparatively little importance. It has been found that the milk of any given woman will show greater variations from day to day than the milk of different women on any one day. Weak women, also, seem to furnish as good a milk as those who are robust and strong, and the milk of women who have borne many children is but little poorer than that of those who are nursing their first infant. Age, also, has little influence, for the milk of women approaching the climacteric has not been found inferior to that of mothers hardly out of their teens. Illness, menstruation, pregnancy, fever, and even severe emotional disturbance, are also almost entirely devoid of any appreciable effect on the composition of the milk. The most striking fact about the composition of the milk, indeed, is its independence of outside influences.²

The fact that a woman has a feeble child is no proof that the milk is at fault. On the contrary, it was found that the milk of women with feeble infants was rather richer than when the suckling was robust. It would almost seem as if there was here a provision of Nature to supply the child which has only strength to draw a small quantity of milk with a food of proportionately better quality.

¹ See also Baumm and Illner, *Samml. Klin. Vorträge (Gynäk.)*, 1894, N.F., 105, 41. These observers found considerably less difference in the composition of the milk at different periods than was shown in the later work of Camerer and Söldner. Monti (*Wiener Klinik*, 1897, Jahrg. xxiii., Hft. 1, 2, 3), says that a child from one to six weeks old should have a wet-nurse whose child is not more than two months. A child from two to four months requires a nurse who has not been suckling for more than three to four months. Whether for older babies a younger nurse is admissible depends on the age of the child. A nurse whose own infant is two to three months old will do for a child of six to eight months, but for a child of over three months the milk of the first weeks is insufficient, and may cause diarrhoea.

² See Baumm and Illner (*loc. cit.*), on whose careful observations and analyses most of the above statements are based.

3. *Influence of the Mother's Diet on the Composition of her Milk.*—Careful observations on this important subject were made by the authors already quoted (Baumm and Illner). They fed various nursing women on the following diets, and analyzed the milk produced on them :

1. An ordinary mixed diet taken in great abundance.
2. A highly nitrogenous diet—*i.e.*, one containing much cheese, eggs and meat.
3. A diet rich in carbohydrates and fat, but poor in nitrogen—*i.e.*, plenty of bread, farinaceous foods, sugar and butter.
4. A very fluid diet.
5. An ordinary diet plus 2 to 3 pints of lager beer daily.
6. A diet consisting largely of salt fish, pickles, and other salt foods.

They found that, in the main, fat was the only ingredient of the milk on which the diet produced any appreciable effect. It was increased, sometimes rising 1 per cent., on the first and second diets only. An abundant supply of carbohydrates had no influence upon the amount of fat. Nor, curiously enough, had the amount of fat consumed in the food; indeed, an increased amount of fat eaten seems to diminish rather than increase the amount of cream in the milk. These results are in harmony with those obtained in the feeding of cows, where a bean diet produces more and richer milk than any other, and the amount of fat in the food is without effect.¹ It is surprising, too, that an increased amount of fluid in the diet does not appreciably increase the total yield of milk. Nor did the diet of salted foods affect the composition of the milk or the health of the child.

On the whole, the results of these and of similar experiments² tend to show that the composition of the milk yielded is to a large extent independent of the diet, just as we have seen it to be of other external conditions. Even if the supply of food is to a large extent cut off, the mother goes on producing milk just as before, only at the expense of her own tissues. Thus, it was found that during the siege of Paris women were able to continue nursing although almost starved to death. The influence of alcohol on the secretion and composition of milk is a subject of great practical importance.³ The experiments just quoted showed that 2 to 3 pints of light

¹ Thomson, 'Food of Animals,' London, 1846, p. 132.

² See Temesváry (*Monatsheft f. Geb. u. Gynäk.*, November, 1900).

³ For an elaborate résumé of our knowledge on this subject, see Rosemann, *Archiv. f. die Ges. Physiolog.*, 1900, lxxviii. 466.

beer daily had no effect on the composition of the milk, and other observers have shown that as much as five glasses of port or champagne are similarly devoid of influence.¹ Physiologically alcohol may be regarded as the nutritive equivalent of a certain amount of fat (p. 340), and as fat in the diet is without favourable influence on the composition of the milk, so, too, is alcohol. The common prescription of stout for nursing mothers is thus devoid of scientific justification, for the nutritive ingredients of stout are its alcohol and a certain proportion of sugar, and both of these are unable to improve the quality of the milk.

On the other hand, the bad effects on the child, which have been attributed to the taking of alcohol by the mother, are equally imaginary, the fear that alcohol will be excreted by the milk being groundless, unless, indeed, the mother indulge in it to the extent of producing intoxication. Distillation of the milk in the above experiments failed to show the presence of any alcohol in it at all.

Alcoholic liquors, then, cannot directly affect the quality of the milk. On the other hand, if a little bitter beer or a glass of wine at meals increases the mother's appetite and her power of digesting ordinary food, then such an addition to her diet will improve her own nutrition and with it the composition of her milk.

Seeing that the composition of the milk is so little affected by diet, one need not jump to the conclusion that if a suckling be suffering from dyspepsia there is some error in the mother's food. So long as the proportion of fat in the milk remains normal, it may be assumed that there is no great fault in the dietary of the mother. On the other hand, if the milk shows a deficiency of fat, the best way to improve its quality is to increase the appetite of the mother for ordinary food, to supply her with that abundantly, and of an easily-digested quality, to let her have four meals daily, and to see that meat or some other form of protein food is well represented in at least three of them.

4. *Influence of Frequency of Suckling on the Composition of the Milk.*—The act of suckling serves as a stimulus to the breast, and if repeated at too short intervals the richness of the milk is increased, and it may become less digestible. Hence, if a child is crying from indigestion, an attempt to quieten it by frequently giving it the breast is sure to lead in the end to the production of an even less digestible milk, and so to an aggravation of the trouble.

¹ Klingemann, quoted by Cautley.

3. AMOUNT OF MILK REQUIRED BY THE CHILD DAILY.

One can only arrive indirectly at the amount of milk which a child should get at each meal and in the course of the day. Arguments from the size of the stomach in infancy are not of much value, for individual variations in the size of the stomach are very wide, and the size after death is no certain criterion of the capacity during life. Nor is the amount of milk in the breast a certain guide, for the child need not exhaust the breast at each meal. A method which has been widely adopted is that of carefully weighing the child before and after each feed. If carried out on a sufficiently large number of infants, this method affords a fairly trustworthy basis from which to arrive at the average quantities required at each age, and it is by such a method that the following tables have been constructed.¹

AMOUNT OF MILK REQUIRED DAILY (CAMERER).

<i>Period.</i>	<i>Quantity in Twenty-four Hours.</i>			<i>Period.</i>	<i>Quantity in Twenty-four Hours.</i>		
1st day	30 grammes.	9th week	..	..	817 grammes.
2nd "	130 "	10th "	..	..	850 "
3rd "	240 "	11th "	..	..	764 "
4th "	290 "	12th "	..	..	767 "
5th "	330 "	13th "	..	..	819 "
6th "	365 "	14th "	..	..	829 "
7th "	400 "	15th "	..	..	838 "
Middle of 2nd week			450 "	16th "	..	..	843 "
End "	500 "	17th "	..	..	851 "
3rd week	497 "	18th "	..	..	875 "
4th "	582 "	19th "	..	..	872 "
5th "	653 "	20th "	..	..	820 "
6th "	734 "	21st "	..	..	862 "
7th "	780 "	22nd "	..	..	848 "
8th "	803 "				

AMOUNT OF MILK REQUIRED DAILY—AVERAGE MEALS (FEER).²

<i>Period</i>	<i>Quantity.</i>	<i>Per Day.</i>
1st week	40 to 50 grammes.	291 grammes
2nd "	80 " 90 "	549 "
3rd to 4th week	85 " 110 "	590 to 652 "
5th " 8th "	120 " 135 "	687 " 804 "
9th " 12th "	140 "	815 " 828 "
13th " 16th "	150 "	852 " 893 "
17th " 20th "	155 "	902 " 947 "
21st " 24th "	160 "	956 " 980 "

¹ It must be noted that the amount taken from the breast at any one meal varies greatly, and this invalidates considerably the trustworthiness of the 'test meal' as an index of the total daily consumption (see Forsyth, 'Observations on Breast Feeds,' *Lancet*, June 24, 1913).

² Quoted by Hauser, *Fortschr. der Med.*, 1897, xv. 929.

AVERAGE MEALS IN ELEVEN BOTTLE-FED BABIES
(SCHMID-MONNARD).¹

Period.				Quantity taken at Each Meal.	
1st to 4th week	..	..	..	185	c.c.
5th " 8th "	..	..	..	215	"
9th " 12th "	..	..	..	230	"
13th " 16th "	..	..	..	260	"
17th " 20th "	..	..	..	270	"
21st " 24th "	..	..	..	270	"
25th " 28th "	..	..	..	290	"
29th " 32nd "	..	..	..	330	"
33rd " 36th "	..	..	..	380	"
37th " 40th "	..	..	..	310	"
41st " 44th "	..	..	..	350	"

The last observer found that the quantity taken at a meal usually surpasses the capacity of the stomach, the explanation of which probably is that the stomach begins to empty itself before the meal is finished.²

Obviously these data must only be regarded as affording average indications. They must not be applied too absolutely to any given child, for small and weakly children will necessarily require less nutriment than those which are heavy and strong, and healthy infants of a few weeks may take as much milk as feebler ones whose age is counted by months. Pritchard has also pointed out that the amount of food required by an infant is greatly influenced by such stimuli to metabolism as exposure to air and light.³

Bearing these precautions in mind, then, one may say that on an average a healthy infant will require—

During 1st to 4th week	..	..	..	600	grammes milk daily.
" 2nd " 4th month	..	..	..	800	" "
" 5th " 7th "	..	..	..	950	" "

The child will require eight meals in the twenty-four hours; therefore a wet-nurse should yield from each breast two or three hours after the last suckling—

In 1st to 4th week	..	..	..	40	grammes.
" 2nd " 4th month	..	..	..	55	"
" 5th " 7th "	..	..	..	65	"

¹ *Jahrb. f. Kinderheilk.*, 1899, xlix. 67.

² See also Feer, *ibid.*, 1906, lxiv. 355, and Mosenthal, *Arch. of Pediatrics*, 1909, xxvi. 761.

³ *Brit. Journ. of Children's Diseases*, xi., 1914, p. 49. Pritchard calculates that a child of three months weighing 11 lbs. should not require less than 23 ozs. of breast-milk daily; one of six months weighing 16½ lbs. less than 30 ozs., and one of nine months less than 36 ozs., daily.

The importance of regularity in the feeding of infants cannot be exaggerated. By proper timing of the meals it can be arranged that the stomach shall have plenty of time to empty itself, and thus one cause of indigestion will be avoided. The child is a creature of habit, and if it be trained to regular feeding hours will not expect feeds between meals. The following table, borrowed from Holt, represents in a convenient form the best intervals for feeding at different ages, and (approximately) the amount of drink to be taken at each meal.¹ The table is constructed in order to afford guidance as to the quantities to be given in artificial feeding, but the same time intervals should be observed when the child is being fed by the breast, although in that case the quantity taken can usually be safely left to be determined by the appetite of the child.

SCHEDULE FOR FEEDING HEALTHY INFANTS DURING THE FIRST YEAR.

Age.	Number of Feedings, Twenty-four Hours.	Interval between Meals by Day.	Night Feedings (10 p.m. to 7 a.m.).	Quantity for One Feeding.		Quantity for Twenty-four Hours.	
				Ounces.	Grammes.	Ounces.	Grammes.
3rd to 7th day	10	2	2	1-1½	30-45	10-15	310-460
2nd and 3rd weeks	10	2	2	1½-3	45-90	15-30	460-930
4th and 5th weeks	9	2	1	2½-3½	75-110	22-32	680-990
6th week to 3rd month	8	2½	1	3-4½	90-140	24-36	740-1,110
3rd to 5th month	7	3	1	4-5½	125-170	28-38	870-1,080
5th to 9th month	6	3	0	5½-7	170-220	33-42	1,020-1,300
9th to 12th month	5	3½	0	7½-9	235-280	37-45	1,150-1,400

As in the previous tables, the *quantities* in this case must again be regarded as only applicable to the healthy child of average weight, and may require to be reduced somewhat for delicate infants. There are two criteria by which one can judge whether the amount given is sufficient: (1) the weight of the child, (2) the character of the stools. Regular weighing is of the greatest importance, and if a

¹ Such a table must be used with some elasticity. In very delicate infants it may be necessary to feed at even shorter intervals, whilst in those which are healthy it is often possible to feed at four-hourly periods quite early.

steady increase in weight be not manifest, there is something wrong with the diet. Inspection of the stools will show whether they contain any undigested milk, and so whether absence of increase in weight be due to deficiency in the amount of the diet or to some error in its quality.

4. DIGESTIBILITY OF HUMAN MILK.

Stomach digestion is not of much importance in infancy. The stomach in early life is small in capacity and of but feeble muscular power, and seems to allow the food introduced into it to pass quickly on into the intestine, where the essential work of digestion takes place. Thus, it has been found,¹ by washing out the stomachs of infants at varying intervals after feeding, that, if 3 ounces of milk be taken at a meal, fully three-fourths of it has left the stomach after the lapse of two hours, and that in another twenty or thirty minutes the stomach is entirely empty.

Whether the milk really clots in the stomach in very early life is disputed, some writers contending that there is no rennet to be found in the stomach during the first month. Whether this be so or not is of little importance, for the clot formed by human milk is, for reasons to be explained later (p. 451), very much looser than the clot formed by cow's milk, and does not offer any serious difficulty to the stomach in its digestion.

The absorption of the constituents of human milk in the intestine of infants seems to be very complete. Protein is said² to be absorbed to the extent of 99 per cent., fat to 97 per cent., and the mineral salts to 90 per cent., while the sugar enters the blood in its entirety. During the first week or so of life, however, the absorption of the fat of the milk does not seem to be always as perfect as these figures would indicate, and a good deal of fat may be found in the motions.³ It would seem, indeed, as if the newly-born infant required a little practice before it is able thoroughly to digest even its mother's milk.

5. NUTRITIVE VALUE OF HUMAN MILK.

Comparing the nutritive value of a given amount of human milk with that of an equal quantity of cow's milk, one may say that the two yield practically the same amount of solid nutriment; but the fuel value of the cow's milk is rather greater than that of human

¹ Van Puteren (Diss. St. Petersburg, 1889), reference in *Jahrb. f. Kinderheilk.*, 1890, xxxi. 188.

² Uffelman, *Deut. Archiv. f. Klin. Med.*, 1881, xxviii. 437.

³ See Blaubeurg, 'Studien über Säuglingsfäces,' Berlin, 1897.

milk, owing to the larger amount of fat which it contains. The difference, however, is not great, for 100 grammes of cow's milk yield 66 Calories, and a similar quantity of human milk 62½ Calories. Both in building material and in fuel value, therefore, human milk is a poorer fluid than the milk of the cow.¹

An ordinary infant, six months of age, consuming the usual amount of breast-milk, will get from it, roughly speaking, the following amounts of nutritive materials :

Protein	..	..	..	14 grammes.
Fat	..	..	..	30 "
Carbohydrates	..	..	..	59 "

These quantities may be compared with the standard for an ordinary man doing moderate work thus:

	<i>Adult at Moderate Work (Voit). (Weight = 70 Kilos.)</i>			<i>Infant of Six Months. (Weight = 6·7 Kilos.)</i>
Protein	118	14
Fat	56	30
Carbohydrate	500	59
Calories	3,054	578

This comparison is also exhibited in a graphic form in Fig. 33. One is at once struck by the relatively large amount of fat which the diet of human milk contains. The infant of six months actually obtains more than half as much of that constituent as the full-grown man. The relation of protein to carbohydrate in the two diets is very similar, but it must be remembered that the man is doing muscular work, while the infant is not. Relatively to weight and mode of life, therefore, the infant is much more abundantly nourished than the adult.²

It will be seen, too, that a nursing mother yields up about one-

¹ The direct observations of Rubner show that 1 litre of human milk yielded in one instance 614·2 Calories, and in another 723·9. A similar quantity of cow's milk yields 690·4. In other words, an average sample of either human or cow's milk may be expected to yield close on 700 Calories per litre. Under the most favourable conditions in the adult, only 90 per cent. of this is available, owing to defective absorption, whereas in the infant, in which the digestion of milk is more perfect, 91 to 91·6 per cent. is available.

² The surface of the child is relatively three times as great as that of the adult. The following table (from Camerer) shows the relation between extent of surface and the Calories supplied in the diet at different periods of life :

<i>Infants.</i>				
Age in weeks	..	..	..	2
Weight in kilos..	..	..	..	3
Calories per square metre of surface	1,020	1,420	1,330	1,270
				1,390

eighth of the protein and carbohydrate in her diet to her child, and fully one-half of the fat, whilst more than one-fifth of the fuel value of her food is also handed over to the infant.

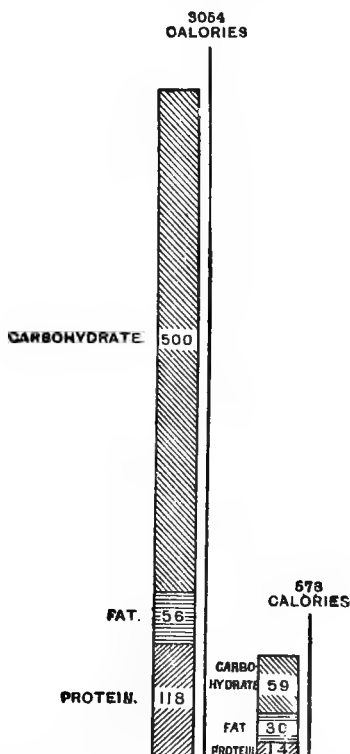


FIG. 33.—COMPARISON OF NUTRITIVE CONSTITUENTS REQUIRED BY AN ADULT AND BY AN INFANT OF SIX MONTHS.

					Boys.			
Age in years	..	..	..	..	3 to 5	7 to 10	11 to 14	15 to 16
Weight in kilos	..	..	..	..	18	24	34	52 „ 58
Calories per square metre of surface					1,680	1,440	1,250	1,220
					Adults.			
Weight	..	..	..	..	65.5 kilos.			
Calories (rest)	..	..	..	..	1,190			
„ (work)	..	..	..	..	1,420			

Immediately after birth, therefore, a child gets a smaller supply of Calories per square metre than an adult, and consequently loses in weight, but later on it gets more per surface area, and is thus able to grow.

Holt and Fales, 'The Food Requirements of Children' (*Amer. Journ. of Diseases of Children*, 1921, xxi, 1), estimate the average Caloric requirements at 100 Calories per kilo at one year of age (weight about 9.5 kilos).

CHAPTER XXV

**THE PRINCIPLES OF FEEDING IN INFANCY AND
CHILDHOOD (*continued*): SUBSTITUTES FOR
HUMAN MILK**

IN the last chapter we learnt that the physiological peculiarities of infancy demand that the diet during that period of life should be relatively rich in protein and mineral matter, and especially so in fat. A consideration of the chemical composition of human milk showed how well adapted it is to meet these demands, while a computation of the amount of it which infants consume at different ages enabled us to form some idea of the quantity of each nutritive ingredient actually required at each period of infancy. Further investigation taught us that human milk is easily disposed of by the infant's stomach, is absorbed very completely in the intestine, and is a fluid of high nutritive value, and therefore eminently adapted for the requirements of the child.

These results of scientific investigation have been long anticipated by experience, and both unite to emphasize the inestimable value to the infant during the first ten months at least of its life of a dietary of human milk. Unfortunately, however, the mother is often unable or unwilling to suckle her infant, and one has to find some substitute for the natural supply. A wet-nurse is, of course, from the infant's point of view, the best alternative, but one need hardly say that this mode of feeding is open to considerable practical disadvantages. One naturally looks next to the milk of other animals. The following table exhibits the approximate composition of the milk of some of the commoner domestic animals compared with that of human milk :

COMPOSITION OF THE MILK OF DIFFERENT ANIMALS.¹

100 Grammes Milk contain in Grammes						
		Protein.	Fat.	Sugar.	Ash.	Other Nitrogenous and Unknown Bodies.
Human	0.9	3.52	6.75	0.19	0.6	
Cow	3.0	3.55	4.51	0.70	0.3	
Goat	2.8	3.40	3.80	0.95	—	
Mare	1.9	1.00	6.33	0.45	0.49	
Ass	1.6	0.93	5.60	0.36	—	

It will be observed that none of these is identical with human milk.

This is not surprising, for the composition of a milk, especially as regards its proteins and mineral constituents, seems to depend upon the rate of growth of the animal for which it is intended. The faster a young animal grows, the richer is the mother's milk in these two ingredients. This fact is brought out very strikingly in the following table:²

		Time by which Weight is Doubled.	100 Parts Milk contain			
			Protein.	Ash.	Lime.	Phosphoric Acid.
Human ..	180 days	1.0	0.2	0.032	0.047	
Horse ..	60 "	2.0	0.4	0.124	0.131	
Calf ..	47 "	3.5	0.7	0.160	0.197	
Goat ..	19 "	4.3	0.8	0.210	0.322	
Pig ..	18 "	5.9	—	—	—	
Sheep ..	10 "	6.5	0.9	0.272	0.412	
Cat ..	9½ "	7.0	1.0	—	—	
Dog ..	8 "	7.3	1.3	0.453	0.493	
Rabbit ..	7 "	10.4	2.4	0.891	0.996	

The milk of the ass has often been stated to be the closest approximation to mother's milk. I have collected the results of all the most recent analyses of it, and compared them with the standard of composition of human milk as follows:

	Ass's Milk (Schlossmann's Analysis). ³	Ellenberger's Analysis.	Average of other Analyses. ⁴	Human Milk. ⁵
Water	88.80	—	90.5	87.60
Protein	1.30	1.2 to 1.7	1.9	1.52
Fat	0.36	0.1 ,, 1.7	1.4	3.28
Sugar	4.94	5 ,, 6	6.3	6.50
Mineral matter ..	0.309	0.3 ,, 0.4	0.4	0.27

It will be observed that ass's milk is poorer in every ingredient except, perhaps, protein and mineral matter. It is especially poor in fat, which is so important to the infant. In addition to this it is

¹ Heubner, 'Ueber Milch und Milchpräparate,' *Zeit. f. Diät. und Physik. Therapie*, 1899, iii. 1.

² Heubner, *Zeit. f. Diät. und Physik. Therapie*, 1899, iii. 1.

³ Schlossmann, *Zeit. f. Physiolog. Chem.*, 1897, xxiii. 258.

⁴ Dujardin Beaumetz, Wynter Blyth, Peligot, Cheadle.

⁵ Camerer and Söldner, *loc. cit.*

stated to be slightly laxative in its effects, and contains relatively more casein and less albumin than human milk, but it resembles the latter in leaving no residue of nuclein or paranuclein on digestion and in having an alkaline reaction. It is expensive also, and difficult to obtain, although one at least of the large London dairy companies now keeps a stock of milch asses for the purpose of supplying it.¹ On the whole, it cannot be said to be in any way superior to the modifications of cow's milk which will be dealt with later.

The same remarks are applicable to **mare's milk** as to ass's, except that the former is richer in sugar. **Goat's milk** is a comparatively strong milk and not any better suited for use in infancy than cow's.

In the vast majority of cases, then, cow's milk must be the substitute, and hence a careful study of the differences, chemical and physiological, between it and human milk is a matter of the first importance.

CHEMICAL DIFFERENCES BETWEEN HUMAN AND COW'S MILK.

(a) *Quantitative Differences.*—Taking the average results of a great number of observations on the general chemical composition of the two milks, one may compare them thus:

	<i>Human Milk.</i>			<i>Cow's Milk.</i>		
Water	87	to	88 per cent.	87	to	88 per cent.
Protein.. ..	1	"	2 "	3	"	4 "
Fat	3	"	4 "	3½	"	4½ "
Sugar	6	"	7 "	4	"	5 "
Mineral matter ..	0·1	"	0·2 "	0·7	"	"
Reaction	Alkaline.			Acid.		

One sees that while the total amount of solids in the two kinds of milk is about the same, yet the relative proportions of the different constituents in the two cases are very different. Cow's milk is the richer in protein, mineral matter, and (to a less degree) in fat; human milk excels in sugar. The superiority of cow's milk in the building materials is no doubt due to the more rapid rate of growth of the calf than of the infant, but the excess of carbohydrate in human milk is rather surprising when one compares the relative muscular activities of the calf and the baby. It suggests that some of the sugar in human milk is intended as a weak form of fuel instead of the more powerful heat-producing fat, and this substitution may be due to human milk having been devised as an infant food

¹ Asses very rarely suffer from tuberculosis, so that the use of their milk is to some extent a safeguard against that disease.

suited to a warmer climate than that which civilized man now occupies.

The proportion of lecithin is also relatively much greater in human than in cow's milk, there being 3.05 parts of lecithin to every 100 parts of protein in the former, and only 1.40 to 100 of protein in the latter. This is probably to be attributed to the relatively greater weight of the brain in the child than in the calf.¹

(b) *Qualitative Differences.*—On more closely examining cow's milk, one finds that the differences in *kind* between its principal ingredients and those of human milk are even greater than the differences in the relative amounts. Sugar, indeed, is the only ingredient which is identical in kind in the two milks; the nitrogenous matters, the fat and the mineral salts must be compared separately in each.

1. **Nitrogenous Matters.**—We have already seen that human milk includes a considerable proportion of unknown 'extractive' bodies which contain nitrogen. Cow's milk contains considerably less of these. One-eleventh of the total nitrogen in human milk is present in the form of extractives, as compared with one-sixteenth in cow's milk.² As to the uses of these extractives to the child we are entirely in the dark, but it is conceivable that too low a proportion of them in the diet may not be free from disadvantages.

The proteins of milk are of two kinds, casein and albumin (Chapter VII.). Cow's milk contains relatively much more of the former, and human milk of the latter. The exact proportions given by different analysts vary considerably, but a reliable estimate has given 4 parts of casein to 1 of albumin in cow's milk, and the proportions of the two in human milk as equal.³ When one remembers that albumin is a much more easily digested form of protein than casein, it is evident that there is here an important practical difference between the two milks. Not only so: the casein itself is actually different in the two forms of milk. Cow's casein leaves behind an indigestible residue (paranuclein); human casein does not.⁴ When an acid is added to cow's milk the casein is thrown down in large flocculi, which do not readily dissolve in excess; under similar treatment human milk yields very fine flocculi which readily go into solution on adding more acid. Lastly,

¹ Burow, 'Der Lecithingehalt der Milch und seine Abhängigkeit vom relativen Hirngewicht des Säuglings,' *Zeit. f. Physiolog. Chemie*, 1900, xxx, 495.

² See Munk, *Virchow's Archiv.*, 1893, cxxxiv, 501; and Camerer and Söldner, *Zeit. f. Biolog.*, 535, 1896.

³ Hammarsten, *Jahres-Ber. f. Thier-Chemie*, 1895, p. 206. For other estimates see Edlefsen, *Munch. Med. Woch.*, xlviii, 7, 901; and Van Slyke, *New York Med. Journ.*, May 25, 1907.

⁴ Szontagh, *Ungar. Archiv. f. Med.*, 1894 (reference in *Jahres-Ber. f. Thier-Chemie*, 1894, xxiv, 209).

human casein is richer in sulphur than the casein of cow's milk. For these reasons human casein is more easily digested.

2. **Fat.**—The fat of human milk contains more oleic acid, and has consequently a lower melting-point and is more easily digested than the fat in cow's milk. This greater digestibility of the fat of human milk is increased by the fact that it is present in a much finer state of division than the fat droplets in cow's milk. Human milk fat contains also much less of the soluble or volatile fatty acids than one finds in the fat of cow's milk¹; the exact significance of this is, however, unknown.

3. **The mineral salts** in the two forms of milk also show important differences. Not only are calcium and phosphorus both present in much smaller amount in human milk, but there are important differences in the form in which the phosphorus occurs in the two cases. In human milk there is only, or almost only, organically combined phosphorus present; in cow's milk less than half is in this form of combination.² In its high proportion of organic phosphorus human milk recalls the chemical peculiarities of plant embryos or the yolk of egg. Considering the great importance of phosphorus in the nutrition of the infant, and the fact that organic combinations of it are probably more easily assimilated than its inorganic salts, one must admit that the differences between human and cow's milk just pointed out are not to be lightly disregarded.

In the light of these facts, regarding the profound qualitative differences in chemical composition between human and cow's milk, one must conclude that it is impossible ever so to modify the latter that it shall be identical with the former. In other words, *a truly 'humanized' cow's milk is a chemical impossibility.*

COMPARATIVE DIGESTIBILITY OF COW'S AND HUMAN MILK.

It is a familiar fact that most young infants have much greater difficulty in digesting cow's milk than that of their own mother.

¹ Laves, *Zeit. f. Physiol. Chem.*, 1894, xix. 369, and Ruppel, *Zeit. f. Biol.*, 1895, xxxi. 1.

² Of the total phosphoric acid in human milk, 35 per cent. is in the form of lecithin.

Of the total phosphoric acid in cow's milk, 5 per cent. is in the form of lecithin.

Of the total phosphoric acid in human milk, 41 per cent. is in the form of phosphocarnic acid.

Of the total phosphoric acid in cow's milk, 6 per cent. is in the form of phosphocarnic acid.

See Siegfried, *Zeit. f. Physiol. Chem.*, 1896, xxii. 575; and Stoklasa, *ibid.*, 1897, xxiii. 343.

Sikes (*Journ. of Physiol.*, 1906, xxxiv. 464) finds that not quite half the total phosphoric acid of human milk is combined with protein. The ratio of protein calcium to total calcium is as 84 to 100.

The chief reason for this is that cow's milk forms a much denser clot in the stomach than human milk.¹

The greater density of the clot is due—(1) to the absolutely larger proportion of casein in cow's milk, and probably also to those chemical differences between cow's and human casein already mentioned; (2) to the smaller proportion of fat and soluble albumin relative to the casein which characterizes cow's milk—the soluble albumin and fat of human milk seem to act mechanically in producing a loose clot; (3) to the fact that cow's milk contains six times as much calcium and three times as much acid as human milk, and the density of the clot depends very much, as was explained in Chapter VII., on the proportions of these two constituents.

For all these reasons cow's milk tends to form a dense, retracted clot in the stomach, while the clot of human milk is loose, friable, and easily broken up.

In the intestine there is much less difference in behaviour between the two milks. The stools of infants fed on cow's milk are richer in mineral matters than those of breast-fed children, but, then, so is the milk on which the latter are fed. A higher proportion of the fat of cow's milk also escapes digestion than is the case with human milk, and probably also a somewhat greater proportion of protein;² certainly the fæces of bottle-fed babies contain more nitrogen than those of infants reared at the breast.

INFANT FEEDING WITH COW'S MILK.

Notwithstanding the pronounced differences in chemical composition and physiological behaviour between cow's and human milk, there are some healthy infants who can be reared on the former without modification.³ This is known as **Budin's method**. In order to carry it out successfully the milk must be sterilized at 212° F. for forty minutes, and should be given in small feeds, the exact amount being controlled by regular weighing of the infant. As a rule, the infant will require about one-tenth to one-seventh of its weight of milk daily, this being administered in divided quantities at the usual intervals. As the child gets older the amount at each feed is increased, while the duration of sterilization is shortened.

¹ Meyer (Abst. in *Maly's Jahrb. Thier-Chemie*, 1906, xxxvi. 676), however, believes that he has shown that it is not the casein of cow's milk which is the cause of difficulty to the infant, but some constituent of the whey.

² See Blauberg, 'Studien über Säuglingsfæces,' pp. 107, 108; Berlin, 1897.

³ Budin, *Bull. de l'Acad. de Méd.*, 1893, 3^{me} sér., xxx. 157; *ibid.*, 1894, 3^{me} sér., xxxii. 67. For a summary of the results yielded by Budin's method and a criticism of it, see Marfan, 'Traité de l'Allaitement,' p. 313; Paris, 1899. It is perhaps better to citrate the undiluted milk (see Mann, 'The Feeding of Babies with Undiluted Citrate Milk,' *Clin. Journ.*, 1914, xliii. 691).

The method has the great advantage of simplicity and of practically ensuring satisfactory growth and the absence of rickets. The fear that it may result in scurvy has been exaggerated. In many cases, however, and certainly by all feeble infants, pure cow's milk will be found difficult of digestion, and requires some modification to render it suited to the digestive capacity.

One way in which this has been done is by the process of 'homogenization,' a mechanical process which reduces the fat to a state of fine emulsion, thus preventing the cream from rising. Milk so treated clots like human milk, and, owing to this and to the fine division of the fat globules, it is very easily digested.¹

From what has been already said, it is evident that any modification can only affect the quantities of the different ingredients in the milk; the distinctive peculiarities of the ingredients as opposed to those of human milk will still remain. By suitable treatment, however, the proportion of casein, calcium, and acid salts present can be reduced, and the digestibility of the milk proportionately raised. We must now consider briefly the different methods by which this can be done.

1. The simplest method is by mere dilution. The problem here is to reduce the casein and mineral matters in the cow's milk, to leave the proportion of fat much as it was, and at the same time to increase the amount of sugar. Taking the average composition of cow's and human milk, and adding 1 part of water to 1 of cow's milk, we get the following comparative results :

	Human Milk.	Cow's Milk.	Cow's Milk and Water, equal parts.
Protein	1.5	3.5	1.75
Fat	3.5	4.0	2.0
Sugar	6.5	4.5	2.25
Mineral matter ..	0.2	0.7	0.35

This makes the proportion of protein about right, but leaves the fat and the sugar too low. If now one adds to every 4 ounces of the mixture 1 medium-sized teaspoonful of milk-sugar² pressed flat and 1 teaspoonful of ordinary centrifugal cream, these defects are rectified, and, except for an excess of mineral matter, the mixture will have approximately the same proportion of each ingredient as human milk. The digestibility of such a mixture is still, however, inferior to that of milk from the breast, for water in this proportion does not prevent the formation of a rather dense clot in the stomach.

¹ Homogenized milk is made at the Lepelletier factory at Carentan (Manche), France, and can be obtained in a sterilized form from Roberts and Co., 76, New Bond Street, W.

² White cane-sugar will also do, but milk-sugar is better

The digestibility of the casein can be increased by the addition of citrate of soda in the proportion of 1 grain to every ounce of cow's milk.¹ This acts, as has been already pointed out, by precipitating the excess of calcium salts, and so causing the casein to set into a less dense curd in the stomach.

In the case of very young or weakly infants, it may be necessary to dilute the milk more freely than in the proportion given above. In such a case a mixture of equal parts of milk, water, and lime-water is to be recommended, cream and sugar being added in proportionately larger quantity.

An ingenious method of overcoming the casein difficulty has been proposed by Von Dungern.² It consists in boiling the milk, cooling to 40° C., and adding some pure rennin. Clotting takes place in two or three minutes, and the milk is then thoroughly shaken until all clots have disappeared. It is then ready for use. By this method the casein is not further clotted on reaching the stomach, and is therefore very easily digested. A combination of rennin and milk-sugar for use in the process is sold under the name of Pegnin.³

2. More elaborate methods are the cream mixtures of Meigs, Rotch, and Biedert.

Meigs⁴ allows a quart of milk to stand for three hours in a cool place in a tall vessel. At the end of that time he carefully decants the upper half of the milk, which is now rich in cream. To every 1½ ounces of this he adds 1 ounce of lime-water and 1½ ounces of sugar-water, which is made by dissolving 8 heaped teaspoonfuls of milk-sugar in 16 ounces of water. This mixture will obviously be poorer in protein than that described above. The same principle is adopted in the modification of milk by the 'Lupa' or 'Reed' Humanizer, both of which are suitable for domestic use.

Rotch's formula⁵ is very similar. He takes

Cream (20% fat)	..	1½ ounces.	|	Water ..	..	..	5 ounces.
Milk .. ..	..	1 ounce.	|	Milk-sugar ..	..	..	3½ drachms.

The mixture is boiled, and when cool ½ ounce of lime-water is added. It is stated to have the following composition :

¹ See a paper by Dr. F. J. Poynton ('The Value of the Addition of Citrate of Soda to Cow's Milk in Infant Feeding'), *Lancet*, 1904, ii. 433.

² *Munch. Med. Woch.*, 1900, xlvii. 1661.

³ Meister, Lucius, and Brüning, 51, St. Mary Axe, E.C.

⁴ 'Archives of Pediatrics,' 1889, vi. 833, and 'Milk Analysis and Infant Feeding,' p. 74; Philadelphia, 1885.

⁵ Described by Cautley, 'Infant Feeding,' p. 150.

Protein	..	..	..	1'2
Fat ..	..	..	..	4'2
Sugar..	..	..	..	6'5

It is rather too rich in fat for general use.

Biedert¹ uses a mixture of 130 c.c. of cream (10 per cent. fat) with 390 of water and 18 grammes of milk-sugar. This results in a milk containing 1 per cent. of casein, $2\frac{1}{2}$ per cent. of fat, and 5 per cent. of sugar. For very young infants the mixture may have to be given more diluted.

3. *Soxhlet*² dilutes the milk with half its volume of a $12\frac{1}{2}$ per cent. solution of milk-sugar. This makes the proportion of protein the same as in human milk, but leaves the fat one-third less and the sugar one-half more. In other words, some of the fat by this method is replaced by sugar. Considering the great importance of fat in the infant economy, it is doubtful if such a substitution is justifiable. Heubner,³ however, reports that he has fed thousands of the most miserable infants on the mixture with the greatest success. It certainly has the merit of simplicity.

4. So-called **humanized milks** are now prepared on a large scale by many dairy companies. By diluting the milk with an equal quantity of water and subjecting it to the action of a centrifuge, it is divided into two equal parts, one of which contains practically all the fat of the original milk but only half of the other ingredients. The deficiency of sugar is remedied by the subsequent addition of that constituent in the necessary proportion. The proportion of protein in such a milk will tend to be somewhat too low, and the mineral matter still too high, but otherwise the composition will correspond pretty closely to that of human milk.

The following analyses of their humanized milks are supplied by the Aylesbury Dairy Company :

	No. 1.	No. 2.	Humanoid (diluted).	Human Milk.
Water ..	89'43	88'3	88'44	87'6
Protein ..	1'3	2'2	1'49	1'5
Fat ..	4'0	3'6	3'59	3'5
Sugar ..	4'7	5'2	6'28	6'5
Mineral matter..	0'49	0'57	0'20	0'27

*Paget's Perfected Milk Food*⁴ is a concentrated humanized milk. When diluted with 2 parts of water it yields a fluid of the following composition :

¹ See Reinach, *Munch. Med. Woch.*, 1899, xlv. 956.

² *Munch. Med. Woch.*, 1893, xl. 61.

³ Heubner, *Berlin. Klin. Woch.*, 1894, xxi. 841.

⁴ Clay, Paget, and Co., Limited, Ebury Street, S.W.

Water	..	..	..	88.04
Protein	..	..	..	1.08
Fat ..	..	..	..	3.83
Sugar	..	..	..	6.82
Mineral matter	..	..	..	0.23

It is sterile and keeps indefinitely. My own examination of it shows that it is certainly rich in fat, and hardly clots at all with rennet. It is, perhaps, somewhat deficient in protein.

One defect common to all the above methods must be pointed out. It is true that they bring the total amount of protein down more or less equal to that found in human milk. They do not, however, influence in any way the relative proportion of the two kinds of protein—casein and albumin. In all of them the former remains relatively higher than in human milk, and the latter relatively lower. For this reason the resulting mixtures must remain more difficult of digestion than human milk. Various methods of getting over this difficulty have been proposed.

*Hammarsten*¹ takes advantage of the fact that whey contains the albumin of the milk but not its casein (see p. 132), and by making a mixture in the following proportions:

Cream	..	..	..	200 parts,
Whey	..	..	..	800 ..

or

Cream	..	..	..	100 parts,
Milk	..	..	..	100 ..
Whey	..	..	..	800 ..

he gets a fluid which contains albumin and casein in the same proportion as in human milk.

*Ashby*² was also a strong believer in the virtues of whey. He prepared it by placing 30 ounces of fresh milk in a Hawksley's sterilizer and heating to 104° F.; two teaspoonfuls of Benger's essence of rennet³ are added, and the bottle set aside for a few minutes. When curdling has taken place the curd is thoroughly broken up by stirring and shaking, and the whey is then strained off through fine muslin. In this way 22 or 23 ounces of opalescent whey are obtained. This is heated to 180° for twenty minutes to destroy the rennin, and is then strained again. The composition of the whey so obtained is as follows:

Protein	..	..	..	0.97	Salts	..	..	..	0.61
Fat ..	..	..	..	2.0					

The whey may be used alone with the sole addition of 2 or 3 drachms of milk-sugar to the pint as a food for newly-born infants.

¹ *Jahres-Ber. f. Thierchemie*, 1895, p. 206.

² *Edinburgh Medical Journal*, 1899, N.S., v. 389.

³ Hansen's Rennet is to be preferred. It is used by cheese-makers, and is more powerful and cheaper than that usually supplied by grocers.

A weak 'humanized' milk may be prepared by mixing 10 ounces of fresh milk with 20 of whey and adding $\frac{1}{2}$ ounce of milk-sugar. It has the following composition :

Protein	..	..	..	1.75	Sugar	..	..	..	6.0
Fat..	..	..	..	2.5	Salts..	..	..	..	0.6

If a milk richer in fat is desired, 'top' milk should be used in the same proportion. To prepare it, let a quart of fresh milk stand in a covered jar in a cold place for four or five hours, remove the upper 10 ounces by skimming, and add to this 20 ounces of sterilized whey and $\frac{1}{2}$ ounce of milk-sugar. The mixture should contain 4 per cent. of fat. A grain or two of bicarbonate of soda may be added to the mixtures to render them alkaline.

*Monti*¹ also recommends the use of whey. For the first three months he employs a mixture of equal parts of milk and whey, after that a mixture of two of milk to one of whey.

*Vigier*² divides the milk into two equal parts. He skims one and adds the cream to the other. The former is then clotted with rennet, and the whey added to the other half. The resulting mixture has the following composition :

Protein	..	..	..	2.36	Fat ..	..	..	..	3.75
Sugar	..	..	..	4.10	Salts	..	..	..	0.75

*Winter*³ goes on a similar plan when he divides the milk into two parts, skims one, and adds the cream to the other. He then coagulates the skimmed portion with rennet, and adds the whey so obtained to the first part. Such a mixture contains the casein and albumin in proper proportions, but is still apt to be deficient in fat.

*Ralph Vincent*⁴ uses fat-whey as a diluent. A quart of milk is placed in a tall jug. Rennet is added and the milk heated to 100° F., with constant stirring by means of a large spoon. As the curd forms it is allowed to settle to the bottom of the jug, and is pressed into a hard lump. The fat-whey is then poured off and heated to 150° F.; it is then cooled rapidly and the required proportion of milk added. 'Fat-whey' differs from ordinary whey in that it contains nearly the whole of the fat of the original milk.

The following are typical mixtures :

				<i>Fat-Whey.</i>		<i>Milk.</i>
At one month old	..	..	..	3 parts	..	1 part
At two months	..	..	..	5 "	..	2 parts
At three months	..	..	..	4 "	..	2 "

¹ *Wiener Klinik*, 1897, xxiii., Hft. 1, 2, and 3.

² Quoted by *Monti*.

³ Quoted by *Rothschild*, 'L'Allaitement Mixte,' etc., Paris, 1898.

⁴ *The Clinical Journal*, August 18, 1920.

As the infant grows older the fat-whey is gradually replaced by milk.

The **advantage of whey as a diluent** is that it is antiscorbutic, and contains albumin and a little fat. It must be admitted, however, that the preparation of the above mixtures demands more time and trouble on the part of the mother or nurse than one can usually count on.

*Lehmann*¹ dilutes the milk till the casein is in proper proportion and then adds sugar and cream. In order to bring up the proportion of albumin, he takes the **white of an egg**, mixes it with four table-spoonfuls of water, and adds one-third of the mixture to the milk.

The albumin of milk can now be obtained in a soluble form—**Albulactin**—and may be used instead of white of egg to enrich cream mixtures in protein or added to diluted milk. It prevents the formation of a dense clot of casein.²

In America the modification of cow's milk to suit the requirements of infancy has been reduced to an exact science. This has been chiefly brought about by the work of Rotch. Milk containing a known proportion of casein is prepared by adding to it standard solutions of cream and milk-sugar in different proportions. A mixture can be prepared of any desired composition. Laboratories have been established in all the principal towns of the United States in which, on the receipt of a physician's formula, a milk containing the exact proportion of each ingredient which the digestive peculiarities of any given infant may necessitate can be dispensed as accurately as a chemist compounds a prescription.³ Useful and desirable as this is in the case of badly nourished or dyspeptic babies, it is an unnecessary refinement in the artificial feeding of healthy infants.

There is still one point in which any of the above modifications of cow's milk is lacking. Human milk as it leaves the breast is practically a sterile fluid; but this is by no means true of cow's milk as it reaches the consumer. It contains, as we have already seen (Chapter VII.), not only the organisms which cause milk to become sour, but also, and not infrequently, the germs of actual disease. These are specially dangerous to infants, because the low degree of acidity which is characteristic of the contents of the infant stomach enables these germs to pass on almost uninjured into the intestine, where they

¹ *Archiv f. d. Ges. Phys.*, 1894, lvi. 558.

² See Alexander and Bullock, *Journ. Amer. Med. Assoc.*, 1910, lv. 1196.

³ Wentworth, however, has shown that the mixture as dispensed does not always exactly conform with the formula ordered ('The Importance of Milk Analysis in Infant Feeding,' *Boston Med. and Surg. Journ.*, 1902, cxlvi. 683; *ibid.*, 1902, cxlvii. 5).

may readily become the seeds of disease. For this reason, then, the destruction of the germs in cow's milk is of the first importance in preparing it as an infant food. The methods by which this may be done have been already considered (Chapter VII.), but it may be repeated here that in most cases simple boiling is sufficient. 'Pasteurization' of the mixture at a temperature of 70° C. will almost certainly ensure the destruction of the disease germs,¹ but if the milk has to be preserved for any length of time 'sterilization' should be carried out. We have already seen that the digestibility and absorption of the milk are not interfered with by such a process to any important extent.²

Reviewing the whole question of the modification of cow's milk, it may be said that the first method described (boiling, with subsequent dilution and addition of cream and sugar) is the best and simplest method for domestic use. The correction of the relative proportions of casein and albumin, although theoretically sound, is practically not a necessity in the case of healthy infants.

When all is said and done, however, cow's milk, no matter how skilfully modified, is much inferior to human milk as a means of feeding infants, this probably depending on those qualitative differences in the composition of the two fluids which no method of modification can entirely overcome.

¹ It has not been conclusively proved capable of destroying the tubercle bacillus.

² The only disadvantage attending the use of boiled or sterilized milk seems to be that it is occasionally the cause of infantile scurvy, otherwise all the advantages are on the side of boiling (see 'Report to the Local Government Board upon the Available Data in Regard to the Value of Boiled Milk as a Food for Infants and Young Animals,' by Dr. Janet Lane Claypon, 1912). It has also been maintained that boiling destroys the fermentative organisms in the milk which antagonize the putrefactive organisms in the intestine, and therefore exposes the infant to a greater risk of 'intestinal toxæmia.' This does not appear in practice to be a very serious danger.

CHAPTER XXVI

THE PRINCIPLES OF FEEDING IN INFANCY AND CHILDHOOD (*continued*): **OTHER SUBSTITUTES FOR HUMAN MILK (PEPTONIZED MILK, CONDENSED MILK, DESICCATED MILK, PROPRIETARY FOODS); FEEDING OF OLDER CHILDREN**

I. PARTIALLY PEPTONIZED MILK.

IT is believed by some authorities that one of the essential differences between the casein of human milk and that of the milk of the cow is that the former is really a stage nearer the digested condition (*i.e.*, peptone) than the latter, and that the greater digestibility of human casein is due to that fact. Whether this be so or not, there can be no doubt that even the partial peptonization of cow's milk renders it much more easy of digestion. Of *complete* peptonization there is no need to speak here. It is of the greatest utility as a temporary expedient in some cases of disease, or in feeble and exhausted babies, but is not really required for healthy infants. Sooner or later the stomach must be educated up to dealing with pure cow's milk, and the sooner the education is begun the better. Partial peptonization, however, may often be had recourse to with advantage as the first stage in this process of education in the case of infants whose stomachs have a greater difficulty than usual in dealing with cow's casein. It can be conveniently carried out by means of *Fairchild's Peptogenic Milk-powder*. Each measure of the powder contains the ferment required to digest a certain quantity of milk, along with some bicarbonate of soda, which renders the milk slightly alkaline, and enough milk-sugar to raise that ingredient to the proportion found in mother's milk.

By following the directions supplied with the powder,¹ the process

¹ In preparing the milk for an infant with a very delicate digestion, it is advisable not to add so much cream as is recommended in the directions. The relative proportions of milk and water and the duration of peptonization can also be varied to suit different cases.

of digestion is only carried so far as partially to change the casein of the milk, sufficient to prevent its clotting, but not enough to absolve the stomach from all further labour. Thus, digestion is rendered easy without the stomach being demoralized. The use of this method is strongly recommended by Professor Chittenden.¹ He analyzed the resulting mixture, and compares it with human milk as follows :

			Human Milk.	Milk prepared by <i>Peptogenic Milk-powder.</i>
Specific gravity	..	..	1031	1032
Water	..	..	86·7	86·0
Protein	..	..	2·0 ²	2·09
Fat	..	..	4·1	4·38
Sugar	..	..	6·9	7·26
Mineral matter	..	..	0·2	0·26
Total solids	..	..	13·2	13·9
Reaction	..	..	Alkaline.	Alkaline.

It will be observed that the two fluids are almost identical in composition. I find, too, that milk prepared by this method does not clot with rennet, even in the presence of a considerable amount of acid.

2. CONDENSED MILK.

The importance of studying condensed milk will be realized when it is learnt that nearly 1,000,000 cwt. of it are imported into this country every year, and there is no commoner substitute for human-milk, especially amongst the poorer classes, than this.

(a) *Chemical Composition.*—Condensed milk is simply cow's milk from which a large proportion of the water has been removed. The removal is effected by evaporation under reduced pressure and with the aid of a greater or less degree of heat. As a rule, the milk is only reduced to one-third of its original volume, so that in order to restore it again to the condition of the original milk all that is necessary is to add to it twice its volume of water. Unfortunately, however, the milk used for condensation is not always pure milk. Very often the cream has been removed from it by a separator, so that the product is really condensed skim milk. Cane-sugar is also frequently added to the milk after condensation, in order to aid in its preservation. As a matter of fact, all the condensed skim milks found in the market have also been sweetened, so that one may divide condensed milks into the following groups:

¹ *New York Medical Journal*, 1896, lxiv. 71.

² The proportion of protein here given is probably too high.

1. Unsweetened and condensed whole milk.
2. Sweetened¹ and condensed whole milk.
3. Sweetened and condensed skim milk.

1. Of the *unsweetened condensed whole milks* there are four examples, which have the following composition²:

Brand.		Total Solids.	Protein.	Fat.	Milk-sugar.
Ideal ..	..	38.0	8.3	12.4	16.0
First Swiss ..	..	36.7	9.7	10.5	14.2
Viking ..	..	34.2	9.0	10.0	13.3
Hollandia ..	..	43.0	11.3	9.8	18.5

If 1 part of such a milk is diluted with 2 parts of water, the resulting fluid corresponds more or less closely to a good sample of pure cow's milk.

One disadvantage of the unsweetened milks is that they are apt to go bad when the tin has been opened. For this reason they should be kept in a cold place. It would be an advantage also if the manufacturers would put up such milk in small tins, one of which would be sufficient for a day's supply.

2. The *sweetened condensed whole milks* contain, as a rule, rather more added cane-sugar than there are solids in the milk. The following is the composition of some of the best brands; they are arranged, again, according to their richness in fat:

Brand.		Total Solids.	Protein.	Fat.	Milk-sugar.	Cane-sugar.
Nestlé ..	..	77.2	9.7	13.7	15.0	37.2
Rose ..	..	76.6	8.3	12.4	17.6	36.1
Milkmaid ..	..	76.3	9.7	11.0	14.6	38.7
Full Weight ..	..	76.5	12.3	11.0	13.5	37.2
Anglo-Swiss ..	..	74.4	8.8	10.8	16.0	37.1

There are many other brands in the market besides these, but none of them is superior to the above.

Now, although the members of this group contain as much fat as the unsweetened condensed milks, yet so much sugar has been added that if they are mixed with only as much water as has been removed in condensation, the resulting fluid would be so sweet that one could hardly drink it. Hence, a degree of dilution is recommended on the tins of these brands which renders it impossible for the resulting fluid to be at all like cow's milk in its proportion of protein and fat.

3. Of the *condensed separated (or skim) milks* there are an immense

¹ The milk may be either fully sweetened by the addition of 35 to 40 per cent. of cane-sugar, or partially sweetened by the addition of smaller quantities up to 18 per cent.

² The analyses of condensed milks in this chapter are taken from Pearmain and Moor's 'Analysis of Food and Drugs,' part i., pp. 69-78.

number in the shops. They resemble in composition the second group just described, except in that they contain almost no fat (always less than 2 per cent.). When diluted in the proportions recommended for infants, the resulting fluid is very poor in protein and almost free from fat, and is therefore entirely unsuited for a baby's nourishment.

It should be noted that the composition of all forms of condensed milk varies considerably, owing to differences in richness of the original milk, and to variations in the degree of condensation and in the amount of sugar which has been added. This is borne out by the following table taken from a Report by Dr. Coutts to the Local Government Board,¹ which is based upon a large number of analyses taken from various sources:

VARIATIONS IN CHEMICAL COMPOSITION OF CERTAIN CLASSES OF CONDENSED MILK.

	<i>Full Cream.</i>				<i>Machine-skimmed Sweetened.</i>	
	<i>Sweetened.</i>		<i>Unsweetened.</i>			
	<i>Lowest.</i>	<i>Highest.</i>	<i>Lowest.</i>	<i>Highest.</i>	<i>Lowest.</i>	<i>Highest.</i>
Total solids per cent. ..	68·1	83·6	29·2	38·0	56·9	79·1
Fat	8·0	13·7	8·2	11·9	0·1	6·5
Protein	7·3	11·4	8·0	10·0	7·6	12·3
Ash	1·6	3·4	1·6	2·5	1·6	2·9
Lactose	11·6	17·6	11·1	16·0	10·9	17·0
Cane-sugar	36·1	44·6	Nil	Nil	30·4	52·6

(b) *Digestibility of Condensed Milk.*—It must be admitted that condensed milk is more easily digested than fresh cow's milk. When diluted in such proportion as to restore them to the condition of ordinary cow's milk, the condensed milks either do not clot with rennet at all, or the resulting curd is much looser than in the case of pure cow's milk.² The presence of acid does not affect the result. The explanation of these facts probably is that

¹ 'An Inquiry as to Condensed Milks, with Special Reference to their Use as Infants' Foods,' 1911.

² The experiments were performed with the First Swiss brand and with Nestlé's.

the casein undergoes some chemical change in the process of condensation which renders it unfitted to form a dense clot. Certainly this greater digestibility is one point in favour of condensed milk, and justifies its occasional use for infants who are entirely unable to digest ordinary cow's milk, even when specially modified.¹

(c) *Nutritive Value and Economy of Condensed Milk.*—The chief defect of condensed milks from a nutritive point of view is that they are apt to contain too little fat. The unsweetened milks are alone satisfactory in this respect. The skim milks are absolutely to be condemned on that account, and even the sweetened *whole* milks, though they contain all the fat of the original milk, yet require so great a degree of dilution, owing to the amount of sugar which they contain, that the product is notably deficient in fat. 'The following table shows the character of the liquid—it cannot be called milk—that is produced by following out the directions on the labels of half a dozen of the *best brands of (sweetened) whole-cream milk*' (Pearmain and Moor):

<i>Sweetened Whole Milk.</i>		<i>Dilution recommended for Household Purposes.</i>	<i>Fat in such Product.</i>	<i>Dilution recommended for Infants' Use.</i>	<i>Fat in such Product.</i>
A	..	1 to 3	2·6 per cent.	1 to 5	1·8 per cent
B	..	1 „ 5	1·6 „	1 „ 14	0·7 „
C	..	1 „ 5	1·6 „	1 „ 14	0·6 „
D	..	1 „ 6	1·4 „	1 „ 15	0·7 „
E	..	1 „ 5	2·1 „	1 „ 14	0·8 „
F	..	1 „ 5	1·7 „	1 „ 14	0·7 „
G	..	1 „ 5	1·7 „	1 „ 14	0·7 „
Human milk	..	—	—	—	3·5 „

There can be no doubt that an immense amount of harm is done to infants by the indiscriminate use of such milks. Babies fed on them may look fat enough, but they are pale and flabby, and often suffer from rickets, for fatness produced by abundance of sugar in the milk is, as has been already pointed out, by no means a sure indication of health, and the pictures of such fat but flabby infants so freely spread abroad by the makers of condensed milks are very deceptive.

If a sweetened condensed milk is used at all, it should only be for a short period (not beyond the first three or four months), and the deficiency of fat should be made good by the addition to the diet of cream or cod-liver oil. Babies of delicate digestion often do well for a time on Nestlé's milk in the proportion of one teaspoonful to six tablespoonfuls of water. Such a mixture

¹ The great degree of dilution in which condensed milk is usually given no doubt also explains in part the ease with which babies digest it.

contains 1.13 per cent. of protein, 1.28 per cent. of fat, and 6.72 per cent. of sugar, and by the addition of one teaspoonful of centrifugal cream to each feed the fat is brought up to 3 per cent. The casein in this mixture, being very dilute, is easily digested, and the relative excess of sugar does no harm if such a method of feeding is not continued beyond the fourth month.

The only kind of condensed milk which can be unreservedly recommended, however, is that made from whole cow's milk without the addition of sugar. If 1 part of such a preparation is diluted with 2 parts of water, the product may be regarded as identical with good cow's milk, and will therefore require further dilution, sweetening, and addition of cream, just as fresh milk does (p 454). Used in this way condensed milk is convenient in cases in which fresh milk is for any reason unobtainable, or for temporary use in the case of infants who are unable to digest the latter. There is, however, one disadvantage in its use which has yet to be mentioned. It has been found that infants fed exclusively on tinned foods are apt to suffer from scurvy. In order to counteract the tendency to this disease, it is well to give infants which are reared on condensed milk a little orange-juice every day.

The question whether condensed milks are to be regarded as sterile or not is one of some importance. It seems to be by no means certain that they are, for the degree of heat to which they are subjected during condensation is not necessarily sufficient to kill all disease germs.¹

As regards the question of economy, there is nothing to be said in favour of condensed milks. The cost of manufacture is bound to add considerably to that of the original milk, and, as a matter of fact, their cost is equivalent to that of cow's milk at nearly 4d per pint.² In other words, the removal of two-thirds of the water from the milk has about doubled its cost.

¹ See 'Report to the Local Government Board upon the Effects of Certain Condensing and Drying Processes used in the Preservation of Milk upon its Bacterial Contents,' by Dr. S. Delépine (Food Reports, No. 21), 1914.

² A tin of condensed milk contains about 290 c.c. This, diluted with 2 parts of water = 870 c.c., or about $1\frac{1}{2}$ pints of cow's milk, and the original tin costs $5\frac{1}{2}$ d.

3. DESICCATED MILK.

Desiccated milk, the general characters of which have already been described (p. 119), is now being largely used in infant feeding. It has the advantage of being convenient, comparatively sterile, and easily digested, and there seems to be no reason to fear that it predisposes either to rickets or scurvy. A full-cream dried milk should contain about 26 per cent. of fat, and if dissolved in the proportion of one part to eight of water, ordinary milk is reconstituted. In order to prepare a solution more nearly resembling human milk, two tablespoonfuls of the dried milk and six teaspoonfuls of sugar may be dissolved in a pint of water. As regards total protein and sugar, such a solution is approximately correct, but it is deficient in fat, which must either be added in the form of cream (1 ounce of 46 per cent. cream), or given in some other shape—for example, cod-liver oil. Many young infants, however, do very well on half-cream dried milk, and digest it better than preparations which contain more fat. The proprietary food Glaxo consists of dried milk, lactose, and cream, in such proportions that when suitably dissolved the solution approximates to human milk in quantitative composition.

4. PROPRIETARY FOODS FOR INFANTS.

There is an immense number of patent infant foods, almost every one of which claims to be 'the best food for infants' or 'a perfect substitute for mother's milk.' These claims are devoid, of course, of all scientific justification, for, as regards the former, no one will deny that the best food for infants is human milk, and as regards the latter, it has already been shown that cow's milk can never be so modified as to resemble human milk in its qualitative composition. Further, the ingredients of any patent food for infants require to be carefully scrutinized, for many of them contain unaltered starch, and starch is not a substance which can be given with impunity to all infants, even although some of them are able to digest a little of it without harm. Many of them, too, are lamentably poor in fat, the importance of which as a constituent of an infant's diet has already been fully insisted upon. A deficiency in protein is another common fault amongst them, and this, especially if combined with

poverty in fat, may explain the frequency with which rickets is observed in babies reared upon such foods. As there is a considerable degree of discrepancy in the published analyses of these preparations, I have submitted the majority of those found on the English market to a fresh examination, and the results, along with a brief description of each particular food, are contained in the following table :

TABLE SHOWING THE COMPOSITION OF INFANT FOODS.

Food.	Water.	Protein. ¹	Fats.	Carbo- hydrate.	Mineral Matter.	General Description and Remarks.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	
Dried human milk ..	—	12.2	26.4	52.4	2.1	The standard of composition to which artificial substances should conform.
GROUP I.						
Allenbury No. 1 (for children below the age of three months)	5.7	9.7	18.5	62.3	3.75	Desiccated cow's milk from which the excess of casein has been removed, and a certain proportion of soluble vegetable albumin, milk, sugar, and cream added. No starch present. Half an ounce in 3 ounces of water for a child aged three months.
Allenbury No. 2 (for children of the age of from three to six months)	3.9	9.2	17.6	66.8	3.50	Resembles the above, but contains some malted flour in addition. No starch present. One ounce in 6 ounces of water for a child aged six months.
Horlick's Malted Milk ..	3.7	13.8	9.0	70.8	2.70	A mixture of desiccated milk (50 per cent.), wheat flour (26½ per cent.), barley malt (23 per cent.), and bicarbonate of soda (¾ per cent.). Contains no unaltered starch when mixed. Three teaspoonsful (equals 22 grammes) in 4 ounces of water for a child aged three months.
Carrick's Soluble Food	5.3	13.6	2.5	76.2	2.25	A mixture of desiccated milk (37½ per cent.), malted wheat flour (17½ per cent.), and milk sugar (25 per cent.). When prepared according to directions the casein is partially digested, but a considerable amount of unchanged starch is left. One part to be mixed with 9 parts of water and boiled for a few minutes.
Neave's Milk Food ..	2.4	20.0	26.0	47.1	4.5	A mixture of dried milk, lactose, and maltose. Contains no starch.
Glaxo	3.5	22.2	27.4	41.0	5.90	Prepared from dried milk, with the addition of cream fat and lactose. All the carbohydrate in the form of milk sugar.
Milo Food	3.6	14.0	5.2	75.3	1.90	A mixture of desiccated Swiss milk, baked wheat flour, and cane sugar (30 per cent.). Contains about 15 per cent. of starch.
Manhu Infant Food ..	8.8	8.7	5.6	75.9	1.00	A mixture of desiccated milk and malted cereals. When prepared according to directions contains a good deal of unaltered starch.
GROUP II.—Class A.						
Mellin's Food	6.3	7.9	Trace	82.0	3.80	A completely malted food. All the carbohydrate in a soluble form. May be regarded as a desiccated malt extract. Half a table-spoonful (about 5 grammes), ½ pint of milk, and ¼ pint of water for a child under the age of three months.
Chelene Maltose Food ..	4.6	5.3	0.27	87.6	2.25	A fully malted food, containing no starch. To be used with milk
Class B.						
Savory and Moore's Food	4.5	10.3	1.4	83.2	0.60	Composed of wheat flour with the addition of malt. When prepared according to directions, most, but not all, of the starch is

with two or three tablespoonsful of cold milk or milk and water, and $\frac{1}{2}$ pint of boiling milk, or milk and water, to be added.

A mixture of wheat flour and pancreatic extract. When prepared according to directions, most, but not all of the starch is converted into soluble forms. The proteid is also partially digested as well as that of the milk used in mixing it. One tablespoonful (about 1 ounce), and four tablespoonsful of cold milk, then add $\frac{1}{2}$ pint of boiling milk and water; set aside in a warm place for fifteen minutes, then bring to the boil.

A mixture of wheat flour and malt. When prepared according to the directions, it still contains some unaltered starch. Designed for children above the age of six months. One tablespoonful (about 1 ounce), a teaspoonful of sugar, and three tablespoonsful of cold water; mix and add $\frac{1}{4}$ pint of boiling milk and water (equal parts).

A malted farinaceous food. When prepared according to the directions, it still contains much unaltered starch. Complete conversion of all starch occurs during mixing. To be given with milk.

A baked flour, containing only 3 per cent. of *soluble* carbohydrates, the remainder being starch. Recommended to be made with milk or water. Made with water alone is totally insufficient food. Resembles the above, but recommended to be made with milk and water.

A thoroughly baked flour to which have been added cane sugar and some extract of bran. It is *not* specially rich in mineral ingredients, but nitrogenous matters are abundant, and it contains much unaltered starch. One-third of an ounce to be mixed with a breakfast-cupful of milk and water (1 part of milk to 2 parts of water).

A highly starchy food prepared from banana flour.

Contains starch when prepared for use.

Ground oats from which the husk has been removed. Rich in protein and mineral matter.

Ground pearl barley, poor in every element except starch and mineral matter.

A finely-ground whole wheat flour. Not much superior in nutritive value to ordinary 'households' flour. Starch entirely unaltered.

A fine oat flour. Somewhat inferior in nutritive value to 'groats.' Starch unaltered.

Benger's Food ..	8.3	10.2	1.2	79.5	0.80	A mixture of wheat flour and pancreatic extract. When prepared according to directions, most, but not all of the starch is converted into soluble forms. The proteid is also partially digested as well as that of the milk used in mixing it. One tablespoonful (about 1 ounce), and four tablespoonsful of cold milk, then add $\frac{1}{2}$ pint of boiling milk and water; set aside in a warm place for fifteen minutes, then bring to the boil.
Allenbury's Malted Food	6.5	9.2	1.0	82.8	0.50	A mixture of wheat flour and malt. When prepared according to the directions, it still contains some unaltered starch. Designed for children above the age of six months. One tablespoonful (about 1 ounce), a teaspoonful of sugar, and three tablespoonsful of cold water; mix and add $\frac{1}{4}$ pint of boiling milk and water (equal parts).
Coombs's Malted Food..	7.9	12.1	2.8	76.8	0.40	A malted farinaceous food. When prepared according to the directions, it still contains much unaltered starch.
Moseley's Food ..	10.8	11.0	0.92	76.4	0.94	Complete conversion of all starch occurs during mixing. To be given with milk.
GROUP III.						
Ridge's Food ..	7.9	9.2	1.0	81.2	0.70	A baked flour, containing only 3 per cent. of <i>soluble</i> carbohydrates, the remainder being starch. Recommended to be made with milk or water.
Neave's Food ..	6.5	10.5	1.0	80.4	1.60	Made with water alone is totally insufficient food. Resembles the above, but recommended to be made with milk and water.
Frame Food Diet ..	5.0	13.4	1.2	79.4	1.00	A thoroughly baked flour to which have been added cane sugar and some extract of bran. It is <i>not</i> specially rich in mineral ingredients, but nitrogenous matters are abundant, and it contains much unaltered starch. One-third of an ounce to be mixed with a breakfast-cupful of milk and water (1 part of milk to 2 parts of water).
Bananina ..	9.5	4.1	0.40	84.0	2.07	A highly starchy food prepared from banana flour.
Cheltime Infants' Food ..	7.2	16.2	3.02	71.0	1.83	Contains starch when prepared for use.
Robinson's Groats ..	10.4	11.3	1.6	75.0	1.70	Ground oats from which the husk has been removed. Rich in protein and mineral matter.
Robinson's Patent Barley	10.1	5.1	0.9	82.0	1.90	Ground pearl barley, poor in every element except starch and mineral matter.
Chapman's Whole Flour	8.4	9.4	2.0	79.3	0.90	A finely-ground whole wheat flour. Not much superior in nutritive value to ordinary 'households' flour. Starch entirely unaltered.
Scott's Oat Flour ..	5.8	9.7	5.0	78.2	1.30	A fine oat flour. Somewhat inferior in nutritive value to 'groats.' Starch unaltered.

¹ Calculated from total N by factor 5.7.

In judging of the value of these numerous preparations, one may divide them into the following groups :

1. *Foods prepared from cow's milk with various additions or alterations, and requiring the addition of water only to be ready for use.* This group includes :

'Allenbury' first and second foods.
 Carnrick's Soluble Food.
 Horlick's Malted Milk.
 Milo Food.
 Manhu Infant Food.
 Neave's Milk Food.
 Glaxo.

Comparing these preparations with the composition of dried human milk (see table), one observes that they are mostly deficient in fat and too rich in carbohydrate. In some of them, also, there is insoluble carbohydrate (starch) present, which is not suitable for infants. The composition of some of them when ready for use is contained in the following table :

	<i>Human Milk.</i> ¹	<i>Allenbury Food, No. 1.</i> ²	<i>Milo Food.</i> ³	<i>Malted Milk.</i> ⁴	<i>Glaxo.</i> ⁵
Water	87·60	88·30	92·76	92·40	91·10
Protein	1·52	1·56	0·81	1·15	2·18
Fat	3·28	3·03	0·36	0·60	2·52
Sugar	6·50	6·47	3·80	5·38	3·68
Mineral matter..	0·27	0·60	0·13	0·29	0·52

The essential constituent of all these foods is dried milk, to which milk-sugar, malted flour, etc., have been added. The casein in all of them, moreover, is easily digested, as it clots loosely, if at all, with rennet. They are therefore often well borne by delicate infants, but their poverty in fat renders them unsuitable for prolonged use. They are also not free from the risk of producing scurvy, although this danger need not be feared if their administration be confined to the first three months of life.

2. The second group consists of *farinaceous foods prepared from cereals (usually wheat), of which the starch has been partly or wholly transformed into soluble substances (dextrins or malt-sugar), and which require the addition of milk to fit them for use.* The group may be subdivided into two classes :

¹ Camerer and Söldner's analysis.

² Analysis by the author.

³ Analyses by Chittenden (*New York Medical Journal*, 1896, lxiv. 17).

⁴ *Ibid.*

⁵ Analysis by Droop Richmond.

(a) Those in which the starch has been transformed before reaching the consumer—*e.g.*, Mellin's Food.

(b) Those which contain malt or pancreatic ferment, which convert the starch when the food is mixed—*e.g.*, Benger's Food, Savory and Moore's Food, Moseley's Food and others.

When one compares the composition of these foods with that of dried human milk, one is struck again by their great deficiency in fat. They are also defective in mineral matter and protein. If mixed with water alone, therefore, these foods could never be true substitutes for human milk. In all of them, however, the addition of some fresh cow's milk is recommended, although the proportion is often very small. They can only be of use in supplementing the diet of infants who are unable to digest much cow's milk, but the only elements they supply are carbohydrate and, to a less extent, protein. Their addition to cow's milk seems also to aid the digestion of the latter, probably by acting mechanically on the curd, as barley-water does. They may also be regarded as useful (though costly) additions to the diet of the infant after its sixth month.

As regards the relative merits of the two classes into which the group is divided, it may be said that there is no advantage in a food in which the conversion of the starch only takes place during the preparation of the food for use. On the other hand, the disadvantages of such a plan are obvious, for the result is at the mercy of the skill and care of the mixer, and, as a matter of fact, the conversion of the starch in many of the second class is by no means complete, even when the directions are carefully followed (see last column of table).

It is undoubtedly better to use a food such as Mellin's, in which the conversion of the starch has been completely carried out in the process of manufacture. The composition of Mellin's Food, when mixed and ready for use, is as follows:

				<i>Human Milk.</i> ¹	<i>Mellin's Food.</i> ²
Water	..	..	..	87.60	88.00
Protein	..	..	..	1.52	2.62
Fat	..	..	..	3.28	2.89
Carbohydrate	..	..	..	6.50	5.98
Mineral matter	..	..	..	0.27	0.47

¹ Analysis by Camerer and Söldner.

² Analysis by Chittenden (*New York Medical Journal*, 1896, lxiv. 71).

3. The third group includes *farinaceous foods in which the starch has not been predigested*. It includes such foods as Ridge's, Neave's, Frame Food Diet, Chapman's Whole Wheat Flour, Robinson's Patent Barley and Groats, and others. These preparations are open to the same objections as those in the second group, with the additional disadvantage that they contain much starch which has either not been acted on at all or only rendered slightly more digestible by the process of baking to which most of them are subjected in the course of manufacture. Now, into the question to what extent infants are able to digest unaltered starch we need not enter here. One may admit that recent observations have shown¹ that even quite young infants are able to digest much more starch than was formerly believed. The practical fact, however, remains, that starch forms no part of the diet of a naturally-fed infant until, at least, after the cutting of some of its teeth; and, further, experience shows that the presence of unaltered starch in the diet of young infants is prone to excite disorders of the stomach and bowels.

A consideration of these facts renders it evident that foods belonging to this group should be avoided altogether before the infant has cut any teeth. Their addition to the diet after that period will undoubtedly furnish the child with an increased amount of protein and carbohydrate, but such articles as rusks, bread-pap, oat flour, and rice² will do so quite as efficiently, are as easy of digestion, and have the practical advantage of being very much cheaper.

It may be convenient to sum up at this point what we have learnt as to the practical rules for guidance in the feeding of infants.

1. Breast milk is always to be preferred; 'humanized milks,' though right in theory, are not found to be perfect substitutes in practice.

2. If the child does not gain, or loses weight, on the breast, try mixed feeding, using the breast along with modified cow's milk.

3. If the breast is inadmissible, a healthy infant *may* be reared on pure sterilized cow's milk; a feeble infant will require modified cow's milk.

4. The simplest method of modification is by dilution with water

¹ See *Berlin, Klin. Woch.*, 1895, xxxii. 201, and a paper by Carstens at the 67ten Versammlung Naturforscher und Ärzte zu Lübeck, 1895, *Med. Abth.*, p. 161, also Parker in Medical Society's Transactions, 1887, x. 319. The whole subject has been discussed more recently by Corlette ('A Review of the Subject of Starch Digestion in Young Infants,' *Australasian Medical Gazette*, 1905, xxiv. 1); and by Cautley ('Starch Digestion in Babies'), *Lancet*, 1909, ii. 1343.

² The starch of oats and rice is more easily digested by infants than any other.

plus the addition of cream and sugar; dilution with fat-whey is preferable but rather more troublesome, and where expense is no objection, one of the humanized milks or a dried milk may be employed.

5. If the infant is unable to digest cow's casein, even when the milk is much diluted, partial peptonization may be carried out.

6. Condensed milks should only be used temporarily—*e.g.*, during digestive disturbance or where fresh milk is unobtainable, or during the first three or four months. The addition of fat will often be necessary.

7. Proprietary foods should be avoided as complete foods for infants if fresh milk is obtainable.

If used before the child has cut its teeth as additions to a diet of milk, those should be employed in which the starch is entirely or mainly converted into soluble forms. The patent foods in which the starch is unconverted possess no advantages as additions to the diet of older children over such simple articles as oat-flour, rusks, and rice, and are considerably more expensive.

In those rare cases in which an infant seems incapable of digesting the casein of cow's milk even when peptonized, it may be necessary to have recourse to various artificial mixtures, such as whey and cream, white of egg and whey, one of the proprietary foods of Group 2 mixed with whey instead of with milk and water, bread jelly,¹ or raw meat juice.

Midelton² strongly recommends the use of eggs in such cases. He advises the following method of procedure for an infant weighing 6 pounds or more at birth:

During the first two days after birth beat up the raw white of a large new-laid hen's egg, add to this water to make 8 ounces, also 40 grains of pure cane-sugar. Strain through butter muslin. Put 1 ounce of this into the feeding bottle, stand it in hot water at 110° until the food is raised to 98° F. Feed every hour and a half.

On the third or fourth day add 5 minims of the yolk of the egg and 5 minims of raw meat juice to each feed.

Increase the quantities gradually as the child grows older, and also add cod-liver oil emulsion to each feed, say 5 minims of a 40 per cent. preparation.

¹ Bread jelly is prepared as follows: A thick slice of bread (4 ounces) is baked in a basin of cold water for six or eight hours and then squeezed out. The pulp is gently boiled in a pint of fresh water for an hour and a half. The gruel thus made is strained, rubbed through a fine hair sieve, and allowed to cool, when it forms a smooth jelly. Enough of this is mixed with warm water to make a food of the consistence of thin cream; a little white sugar may be added (Cheadle).

² *Brit. Med. Journ.*, 1907, i. 1302.

THE FEEDING OF OLDER CHILDREN.¹

After weaning—which should take place not later than the tenth month—the diet becomes of a more solid character. The same principles must be observed in its composition, however, as in the case of infants; that is to say, the building material and fat must be relatively more largely represented than in the diet of adults.

The importance of a sufficiency of protein in the diet of children can hardly be exaggerated. Much of the feebleness, flabbiness, and pallor of the children of the poorer classes in large towns is no doubt due to a lack of it. There is reason also to believe that a similar deficiency may be a cause of the stunted and ill-developed bodies which such children often show. The dearth of meat is largely responsible for these conditions²

The following computations have been made of the amount of each nutritive ingredient required at different ages³ (see also p. 45):

Age.	Protein.	Fat.	Carbohydrate.
1½ years ..	42·5 grammes.	35 grammes.	100 grammes.
2 " ..	45·5 "	36 "	110 "
3 " ..	50 "	38 "	120 "
4 " ..	53 "	41·5 "	135 "
5 " ..	56 "	43 "	145 "
8 to 9 years ..	60 "	44 "	150 "
12 to 13 " ..	72 "	47 "	245 "
14 to 15 " ..	79 "	48 "	270 "

Atwater's calculation is as follows:

A child under 2 years requires 0·3 the food of a man at moderate work.				
A child of 3 to 5 years requires 0·4	"	"	"	"
A child of 6 to 9 years requires 0·5	"	"	"	"
A child of 10 to 13 years requires 0·6	"	"	"	"
A girl of 14 to 16 years requires 0·7	"	"	"	"
A boy of 14 to 16 years requires 0·8	"	"	"	"

The ratio of building material (protein) to carbohydrate and fat is as 1 : 4·2–4·8 in the average child's diet. In that of the adult at moderate work it is as 1 : 5·3–5·5. It will be noted also that fat is relatively more abundant in the diet of the child. There is 1 part of fat to 3·7 of carbohydrate in the child's diet, while the proportion in the adult is 1 to 4 (Atwater), 1 to 4·8 (Moleschott), and 1 to 8·8 (Voit).

¹ For a discussion of this subject see Dr. Joseph E. Winter's 'The Food Factor as a Cause of Health and Disease during Childhood' (New York: William Wood and Co., 1902).

² See also Clement Duke's 'School Diet,' second edition, chapter iii.

³ Schröder, 'Ueber die Ernährung 8-15 jähriger Kinder,' *Archiv. f. Hygiene*, 1886, iv. 39. See also diagram, p. 47, and a paper by Heubner ('Eine Betrachtung ueber die Ernährung des Kindes jenerseits der Säuglingsalters,' in Jacobi's 'Festschrift,' p. 290).

Roughly speaking, a child of five requires half as much fat and building material as a full-grown man doing a moderate amount of work, but only one-third as much carbohydrate; while a boy of fifteen will require as much of every ingredient as a full-grown man leading a sedentary life.

One must now say a few words as to the sources from which the different ingredients of the diet should be derived.

Even for some time after weaning, cow's milk should still be the chief source of protein. It may be supplemented at the end of the first year by small quantities of yolk of egg, and chicken, fish, and a little underdone meat may gradually be added. These animal substances are the best sources of protein, because they contain it in a concentrated and easily-digested form. It is possible, however, to rear healthy children on a diet the protein part of which is almost entirely derived from vegetable sources,¹ especially if the child is able to lead an active and out-of-door life.

Thus, a German author has recorded the case of an institution in which only one-eighth of the protein in the children's diet was derived from animal sources, and yet the inmates were all well nourished and fully developed. He attributes this good result to the fact that the children were working out of doors most of the day, and were accustomed to the diet from their infancy.

In most cases, however, it is safer to supply at least one-third of the total protein required in an animal form.²

The best vegetable protein-yielders for children are oats (oat flour, groats, and rolled oats), wheat (whole wheat flour, macaroni, semolina, or such patent wheat foods as Opmus and Florador), such preparations of maize as hominy and cerealine, and, amongst the pulses, lentil flour.

Fat should be derived from such sources as good milk, butter, the yolk of egg, and bacon. Difficulty is often found in getting the child to take enough fat, but its importance in the diet is such that pains should be taken to educate the child in this respect. By giving it in a state of fine division the difficulty may often be over-

¹ See cases described by Schröder, *loc. cit.*, p. 453.

² 'During the period of growth,' says Clement Dukes ('School Diet,' p. 32), 'there should be a tolerably even balance between the amounts of farinaceous and vegetable food, with a large preponderance of animal food, the total supply required being largely in excess of that demanded by adults, in order to supply the material necessary for growth and development as well as wear and tear.' He is assuming, of course, that regular daily exercise is enforced. He is of opinion that growing boys should have meat twice a day—once to make good wear and tear, and once to provide for growth. The total daily allowance should be 9½ ounces of cooked meat.

come. Thus, butter spread on bread or mixed with mashed potato may be taken when more solid fat would disagree or be refused. Suet pudding also contains fat in an easily-digested form.

If any **carbohydrate** be added to the diet at all before the teeth are cut, it should, as we have seen, be in a soluble form. In other words, it should consist of some form of sugar or dextrin, starch being excluded. Even up to the end of the first year it is well to avoid purely starchy foods, unless in very limited amount. It is at this period that one of the patent foods, in which the starch is partially digested, may be of service. After the first year more solid starchy food may be given. Rice, potato and oat flour are the most easily digested forms. Biscuits or rusks, too, are more easily digested than ordinary bread, because the high degree of heat to which they have been exposed ruptures many of the starch grains, and converts part at least of their contents into soluble forms.

The following is an analysis of two such preparations :

RUSKS (MONTGOMERIE'S).				DORINA NURSERY BISCUITS.			
<i>Dr. Fago's Analysis.</i>				<i>Dr. Gregory's Analysis.</i>			
Water	6.9			Water	7.94		
Protein	11.5			Protein	9.41		
Starch	60.4			Starch	47.33		
Maltose	14.2			Maltose	16.62		
Other soluble matters ..	6.0			Dextrin	10.58		
Phosphoric acid	0.3			Fat	9.88		
Rest of ash	0.4			Ash	1.24		

The negroes; who live largely on sugar-cane, have the finest teeth the world can show. If injudiciously taken, sugar may, however, injure the child's appetite and digestion. The craving for sweets which children show is no doubt the natural expression of a physiological need, but they should be taken with, and not between, meals. Chocolate is one of the most wholesome and nutritious forms of such sweets (p. 275). Jam is also an important vehicle for adding carbohydrate to the dietary. The claims of jam *versus* butter have already been considered (p. 137); but I would only point out here that so great is the importance of fat in the diet of childhood, and so few the forms in which it can be given when compared with the abundant choice of different varieties of carbohydrate, that one must on no account allow jam to replace butter, or even dripping, as the habitual accompaniment of the child's bread.

The **mineral matters**, which are so important for building up the bones, muscles and blood of the growing child, should be chiefly derived, during the first two years at least, from milk. Abundance of milk in the diet will ensure a sufficient supply of the three most important ingredients—lime, potash and phosphoric acid.¹ Eggs, too, are rich in these elements, and the yolk of egg especially shares with milk the advantage of containing much phosphorus in an organic form. Iron is contained in yolk of egg, the red meats, and in such vegetable substances as oatmeal.

The vegetable salts of potash, which occur so abundantly in fruits and green vegetables, are also of importance, and such articles should always find a place in the child's menu.

Of beverages it need merely be said that water is the only one suited for young children, but care should be taken that it is pure. Alcohol in all forms should be avoided as being entirely unnecessary for healthy children. Tea and coffee are also harmful to the susceptible nervous system of the child, but cocoa, made with plenty of milk, may be allowed, though it should be regarded, like milk, as a food rather than a beverage properly so called.

Schemes of diet for children of school age will be found in the work of Dr. Clement Dukes already referred to.²

The following schemes of diet for young children illustrate the practical application of the above principles :

¹ Dr. Ferguson, the factory inspector, concluded from careful continuous measurements of factory children that between thirteen and sixteen years of age they grow nearly four times as fast on milk for breakfast and supper as on tea and coffee.

² 'School Diet,' p. 174 *et seq.* (London : Rivingtons, 1899).

I. DIET FROM 9 TO 12 MONTHS.

First Meal, 7.30 a.m.

Milk thickened with groats, oat-flour, Chapman's Whole Wheat Flour, Mellin's Food, Savory and Moore's Food, or Allenbury No. 3.

Second Meal, 10.30 to 11 a.m.

Warm milk, pure or diluted with one-third of lime-water.

Third Meal, 1.30 to 2 p.m.

Warm milk, with the addition of the yolk of a lightly boiled or raw egg. A little veal broth or good beef-tea occasionally as a change.

Fourth Meal, 5 p.m.

Same as first.

Fifth Meal, 9 to 10 p.m.

Warm milk.

During this period the use of a bottle should be gradually discontinued, and the child fed with a spoon or accustomed to drink out of a feeding cup or ordinary cup.

The amount of milk taken in the course of the day should not exceed two pints. If the child be thirsty, he may be given a little water between meals.

From about the tenth month onwards, something to chew should be given occasionally, such as a rusk or crust, or a piece of sponge cake or stale bread-and-butter.

II. DIET FROM 12 TO 18 MONTHS.

First Meal, 7.30 a.m.

A breakfast-cupful of milk thickened with groats, fine oatmeal, whole wheat flour, or hominy.

Bread or rusks and milk as a change.

Second Meal about 11 a.m.

A cupful of warm milk, pure or with the addition of one-third lime-water.

Third Meal, 1 to 1.30 p.m.

Beef-tea, mutton or chicken broth, thickened with bread crumbs or sieved potato; as a change, the yolk of a lightly boiled egg.

Some milky rice or bread pudding, with the addition of some of the pulp of a roasted apple or the pulp of stewed prunes.

Fourth Meal, 5 p.m.

Milk and bread-and-butter.

Fifth Meal, 9 p.m.

Warm milk.

III. DIET FROM 18 MONTHS TO 3 YEARS.

First Meal, 8 a.m.

Porridge and milk, followed by the yolk of a lightly boiled egg or bread dipped in bacon fat. Stale bread, crisp toast or a rusk.
Milk to drink.

Second Meal, 12.30 to 1 p.m.

A little pounded or minced chicken or underdone meat or fish.
Milk pudding and stewed fruit.
Water to drink.

Third Meal, 4.30 p.m.

Bread-and-butter ; sponge or other plain cake occasionally.
Milk.

Fourth Meal, 6.30 p.m.

Warm milk and a biscuit.

CHAPTER XXVII

THE PRINCIPLES OF FEEDING IN DISEASE

IN this and the succeeding chapter we shall consider the use of food as a therapeutic agent in the treatment of the sick. In dealing with this part of the subject, it will be well to confine our attention as far as possible to the discussion of principles, and to avoid those detailed instructions for the dietetic management of particular cases which find their appropriate place in text-books of therapeutics. If the general principles involved are once fairly grasped, the knowledge we have already acquired as to the composition and uses of different foods should be sufficient to guide us in drawing up a dietary suited to any ordinary case of illness. Nor can one deal in such a book as this with the methods of preparing food for the sick, or invalid cookery, no matter how important some acquaintance with that art must always be to the practical physician.

In deciding upon the dietetic management of any case of disease it is important to bear in mind, what is often forgotten, that a patient is not a mere bundle of separate organs, but an organic whole, and that the diet must often be directed to the needs of the man rather than to those of his malady. The evil results of a forgetfulness of this fact are often seen. A patient's general nutrition may become seriously impaired, for instance, through well-intentioned efforts to lighten the labours of his stomach, or his heart may become enfeebled in consequence of a regimen designed to lessen the work of his kidneys. The important factor of idiosyncrasy must also be borne in mind, and full recognition made of the fact that different individuals react differently to the same diet just as they do to the same drugs. Nor must it be supposed, as the laity are apparently tempted to do, that diet is a universal panacea which can be counted upon to prevent or to cure all diseases. On the contrary, it has, like other remedial agents, only a limited place in therapeutics, and the few diseases which specially lend themselves to dietetic treatment may

be divided into the following groups: (1) Fevers; (2) disorders of metabolism, *e.g.*, diabetes, obesity, gout; (3) affections of the stomach and bowels; (4) disorders of the circulation and blood (5) diseases of the organs of excretion.

Before, however, one passes to the separate consideration of these groups, it is advisable to point out a few **practical rules** which should always be present to one's mind in drawing up any scheme of diet for a patient. They are these:

1. In acute disease it is well to recommend a special plan of diet; in chronic cases it is often more convenient simply to forbid those articles which are likely to prove harmful.

The next two rules are corollaries to the first.

2. Before recommending any article it is well to ascertain whether the patient likes it, and how it agrees with him.

3. No article should be forbidden unless one has good reason for doing so.

4. Unless there is some strong contra-indication, attention should always be paid to the wishes and tastes of the patient. This rule was first formulated by Hippocrates in the aphorism, 'Such food as is most grateful, though not so wholesome, is to be preferred to that which is better, but distasteful'; and Sydenham recognised its value when he wrote: 'More importance is to be attached to the desires and feelings of the patient, provided they are not excessive or dangerous, than to doubtful and fallacious rules of medical art.'

5. If any article of food disagrees, it is better to reduce the quantity of it taken than to cut it out of the dietary altogether.

6. Changes of diet should, if possible, be made gradually.

7. One should never prescribe a diet for a patient without having first ascertained what his habits are as regards work and exercise.

These rules require no comment.

1. Principles of Diet in Fever.

There are few departments of practical medicine in which opinion has undergone a greater revolution than in the question of fever diet.¹ Hippocrates fed his fever cases simply upon wine and 'ptisan,' or thin barley gruel, and this lowering plan, first practised for centuries on the sole weight of his authority, was afterwards endorsed by the erroneous pathological doctrine first promulgated by Broussais, that fevers proceeded from irritation of the intestinal

¹ For a full account of the history of the subject, see J. Uffelman, 'Die Diät in den Acut-fieberhaften Krankheiten,' 1877.

mucous membrane, and therefore demanded a starvation diet. His contemporary, Brown, though perhaps not much nearer the truth in his pathology, was better advised in his practice when he taught that fevers were 'asthenic' diseases, and required to be treated by liberal feeding. It was not until about the middle of the nineteenth century, however, that Graves, discarding all pathological doctrines, and guided simply by the results of observation, came to the conclusion that the popular starvation method was wrong, and introduced the modern practice, ever since adopted, of 'feeding fevers.'

The prevailing system at the present time may be fairly described as that of feeding a fever patient up to the limits of his digestive capacity with fluid or semi-fluid food, except, perhaps, in the case of some abdominal fevers. The reaction against the starvation plan has, it will be admitted, gone, if anything, rather too far, and the danger now is that too much rather than too little nourishment may be given.

Any lingering doubts as to the wisdom of the feeding plan tend to be dispelled by the results of recent research, which have shown (1) that the free administration of food does *not*, as was formerly supposed, tend to raise the temperature of feverish patients;¹ and (2) that the food is *not* merely poured into a digestive apparatus unable to deal with it, for the absorption of light articles of diet, at any rate, goes on almost as perfectly in the febrile as in the non-febrile state.²

Granted, then, that the liberal administration of food in fever is justified on grounds alike of experience and pathology, we have next to inquire, **What nutritive constituents should the diet of fever chiefly contain?**

A study of the metabolic changes in fever may be expected to afford us some light here. Extensive investigation into these changes in recent years has tended to show that the leading characteristic of the metabolism of fever is a great increase in the destruction of nitrogen-containing tissues, while the mainly carbonaceous components of the body, such as fat, are affected in a much smaller degree.

The reason for the increased destruction of nitrogenous tissues in fever appears to be twofold: First, and probably mainly, it is due to simple inanition, to the fact that less food is reaching the tissues

¹ Von Hoesslin, *Virchow's Archiv.*, 1882, lxxxix. 95, 303. He found that in cases of typhoid the temperature on days when food was administered was only from 0.11° C. to 0.3° C. higher than on starvation days.

² *Ibid.* See also Leyden's 'Handbuch der Ernährungstherapie,' p. 403.

than is required to meet their output of heat. In part, however, it seems also to be due to the fact that the 'toxins' which produce fever exert a specially destructive influence on the protein constituents of the body.

This being so, it seems natural to suppose that the chief dietetic indication in fever must be to supply a large proportion of protein in the diet. Actual observation, however, has shown that it is impossible to bring about a condition of nitrogenous equilibrium in acute fevers on any feasible quantity of food. The reason for this probably is, that although one may cover the waste which is due to simple inanition, it is impossible to prevent that which is brought about by the destructive action of toxins on the cells. Practically, therefore, the administration of a large quantity of protein in the diet fails to achieve the desired result, no matter how strongly it may be indicated theoretically. The consumption of much nitrogenous food has also this disadvantage, that it tends to flood the circulation with the products of nitrogenous waste, already too abundantly present, thus increasing the strain thrown upon the kidneys, and at the same time, in all probability, tending to bring about a condition of toxæmia, to which some of the symptoms of fever are no doubt due.

We shall, therefore, better attain our object of limiting protein destruction by seeing that the 'protein-sparers' are abundantly represented in the diet rather than by devoting too much attention to the proteins themselves.

Now, the protein-sparers, as we have seen, are, in order of their importance, gelatin, carbohydrates, and fats. The use of the first of these is restricted by the fact that the end-products of its destruction are so similar to those of proteins that they may be expected to produce the same results as these in the circulation, while the employment of the last is rendered impracticable by the insuperable repugnance which feverish patients exhibit to fatty foods. We therefore arrive at the conclusion that **the diet of fever should contain a liberal supply of carbohydrates.**

The contention that mineral matters should also be freely represented—a contention based entirely upon theoretical grounds—has already been dealt with (p. 106).

These being the dietetic indications derived from a study of the morbid metabolism of fever, we may next proceed to inquire how they may best be put into practice.

And first, by common consent, the diet of fever is a **fluid diet**. This is not merely grateful to a thirsty patient, but evades the necessity of chewing, which the diminution of the salivary secretion

renders difficult. It has also the advantage of supplying much water to the tissues, of which in fever they seem to stand specially in need. Milk is the simplest, most accessible, and most nutritious of fluid foods, and should always form the basis of the diet. Four pints of it a day will supply about 1,700 Calories of energy to the body, and this, though quite insufficient for the needs of health, is usually enough to meet the demands of a patient confined to bed, especially in fevers of short duration, where the body can afford to draw to some extent upon its own resources. The milk may be given plain or diluted with some alkaline or effervescing water or lime-water. If the patient tires of it, it may be flavoured with a little cold coffee or with caramel or malt extract. If it produces vomiting or diarrhoea, it may be necessary to give it peptonized or to substitute koumiss.

If less than 3 pints of milk can be got down in the day, nutrition is likely to become seriously impaired, and in that case it may be well to 'fortify' the milk. The amount of protein in it may be increased by the addition of such preparations as Casumen, Plasmon, or Somatose, or the proportion of fat may be raised by the addition of cream. For the reasons already given, however, it is better to enrich the milk chiefly by the addition of some carbohydrate. Of these milk-sugar is one of the simplest and best, and is probably not sufficiently made use of. One or two teaspoonfuls dissolved in a little hot water may be added to each tumblerful of milk. The value of sugar in fevers has been specially insisted upon by Fick;¹ and, of all forms of it, milk-sugar, from the comparative absence of sweetness which characterizes it, is probably best.

Instead of using sugar, the milk may be enriched by the addition of some cereal preparation, such as oat-flour, arrowroot, or corn-flour, made in the form of a thin gruel. Many of the patent foods, such as Benger's, Nestlé's, or Malted Milk, may here play a useful part, while some patients find the addition of malt extract agreeable; a tablespoonful of it may be added to each $\frac{1}{2}$ pint of warm milk. In any case, it is well to employ these different devices in turn, for patients quickly tire of any one of them.

In addition to milk, soups, beef-tea, or broths may be allowed in the proportion of about 1 pint a day, but it should be remembered that their chief use is as excitors of appetite, and perhaps as slight stimulants, rather than as foods. They may also be made the vehicles for conveying carbohydrates into the body by thickening them with baked flour or some other simple farinaceous prepara-

¹ *Zeit. j. Klin. Med.*, 1886, x. 531.

tion, or with one or other of the patent protein or carbohydrate foods. Where diarrhœa is present, the use of soups, etc., containing meat extractives is better avoided.

The consumption of beef-juices in fever, though very popular, is to be deprecated for the reasons given in another chapter (Chapter VI.); but the egg-white mixture already described (p. 102) may sometimes be a useful aid in cases where very little food can be taken at one time, and where vomiting is urgent.

Jellies may also be allowed in moderation, those flavoured with wine being perhaps the best, but it must be recollected that their nutritive value is but small.

As regards the **intervals at which food should be given** in fever, one must be guided chiefly by the digestive powers of the patient. It is well to begin with small quantities—say a wineglassful of milk—every hour or so, and gradually feel one's way till a tumblerful can be taken every two hours. Beef-tea can be given after every two of the milk-feeds, as a change. As far as possible the administration of food should be confined to the day hours, a little drink only being allowed during the night; but if the patient is much exhausted it may be necessary to feed by night also.

Cold water is the best **beverage** in fever, but though the total amount of it need not be restricted, it is well only to allow a few sips of it at one time. The excessive consumption of aerated beverages is to be avoided, as tending to overdistend the stomach with gas. In addition to water, milk-sugar lemonade (a teaspoonful to the tumbler, flavoured with a squeeze of lemon-juice), fruit drinks—*e.g.*, unfermented grape-juice or raspberry vinegar and water—or Imperial Drink, are all refreshing, and may be made the means of conveying some sugar into the stomach.

Where there is any tendency to looseness of the bowels, however, it is well to restrict the drink to plain water or barley-water. A cup of tea or coffee may also be allowed if the patient desires it, especially in the early morning, and is probably too often forbidden without any sufficient reason.

The use of **alcohol** in fevers is an important matter which calls for some special discussion. Hippocrates recognised the value of wine in fever, and since his time it has been pretty generally employed. Stokes of Dublin laid down certain imperative indications for its use, and his colleague Graves devoted one of his clinical lectures to a consideration of the place which it should take in the general treatment of fever. The advantages of stimulants, however,

were insisted upon more strongly by Todd,¹ about the middle of the nineteenth century, than by any preceding English author, and the present general recognition of their utility is no doubt largely due to his almost too strenuous advocacy. Indeed, it may be questioned whether in this case also the reaction in favour of a 'stimulating' treatment of fevers has not gone too far, and the administration of alcohol become too much a matter of routine. In a previous chapter we have learned that alcohol has a stimulating influence upon the heart, that it reduces body temperature by dilating the surface bloodvessels, and that it is in itself at the same time a source of energy, and diminishes tissue waste, especially the waste of fat. All of these properties mark alcohol out as an agent likely to be useful in the treatment of such a condition as fever. It would be a mistake, however, to suppose that it requires to be made use of in every case. Clinical observation has shown that it is only imperatively demanded when the following indications are present:

1. Failing circulation, as exhibited (1) in a persistently rapid pulse (120 or more), or if it be weak, irregular, unequal, or dicrotic; (2) by a faint or inaudible first sound of the heart.²
2. Nervous exhaustion, as manifested by sleeplessness, low delirium, and tremors.
3. Failure of digestive-power, as indicated by inability to take food, diarrhoea, and dryness of tongue.
4. High temperature, especially if persistent.
5. A bad general condition—*e.g.*, in feeble, exhausted, elderly, or alcoholic subjects.

In some special diseases—*e.g.*, malaria, erysipelas, and septic poisonings, alcohol seems to increase the resisting-power of the patient and is almost always indicated on that account.

The form in which alcohol should be given in fevers is not a matter of indifference. If one merely wishes to obtain its effects upon the temperature and circulation, any pure form of spirit will do. Sound malt whisky is as good as any other. Where, however, there are signs of nervous exhaustion—as, for example, in the 'typhoid state'—a preparation rich in volatile ethers should be selected. Of these *genuine* cognac is one of the best, and it is worth while to pay a high price for it in order to be sure of having it good. The ordinary so-called brandy is no better than whisky. Possibly the Spanish

¹ 'Clinical Lectures on Certain Acute Diseases,' London, 1860. Lecture XIV., 'On the Therapeutical Action of Alcohol.'

² See Stokes, *Dublin Med. Journ.* (1st series), 1839, xv. 1.

orandy recently introduced may prove useful, as it is said to be rich in ethers. Failing good brandy, one may fall back on one of the stronger wines, and of these old sherry is more highly ethereal than any other.¹ In catarrhal conditions, and where a tendency to vomiting is present, an effervescing wine, such as good, *dry* champagne, often gives the best results. In some forms of delirium, on the other hand, such as that due to alcoholism, bottled stout seems to exert a peculiarly sedative influence.

In deciding upon the **amount of alcohol** to be given, and the frequency of its administration, one must be guided chiefly by the urgency of the indications calling for its use. Half an ounce of spirit, diluted with twice as much water, or an ounce of one of the stronger wines, may be given every four, three, or two hours, according to the effect produced, or even every hour if occasion demands it. Careful observation of the case will generally show whether the right amount is being administered. As long as the pulse is becoming slower and steadier, the skin and tongue more moist, the appetite better, and the patient quieter and calmer, the alcohol is doing good. The results of excessive dosage will usually first manifest themselves in the digestive organs in the form of flatulence, eructation, and dryness of the mouth, with the appearance of sordes on the lips. A tendency to coma, and a persistent smell of alcohol in the breath, are also signs that too much is being given.

DIET IN SPECIAL FEVERS.

The principles of diet described in the preceding pages are applicable to the majority of cases of fever, but in some one requires to introduce modifications. As has already been mentioned, the use of beef-tea and all fluids containing the extractives of meat is best avoided in cases in which there is diarrhœa. The same holds good for **rheumatic fever**. In that disease preparations derived from meat are generally held to be injurious, and the diet during the height of the attack should consist of milk alone or diluted with some alkaline water. Alcohol, also, is usually unnecessary, and to be avoided in these cases.

The dietetic treatment of **typhoid fever** is described in so much detail in all text-books of medicine that it need not be fully described here. It is sufficient to point out that the majority of observers are in favour of a strictly fluid diet, consisting mainly of milk, in that

¹ See Anstie, 'On the Use of Wines in Health and Disease,' p. 44; London: Macmillan and Co., 1877.

disease, and many recommend that even milk should not be allowed in large amount, but that whey should be used in its place.

If curds appear in the stools the milk should be peptonized, but if the case is running a favourable course the nutritive value of the diet may be increased by the addition to the milk of Plasmon or Casumen, Arrowroot, Maltine, biscuit powder, or one of the infant foods. Tea or coffee may be allowed in moderation, and the monotony of the diet varied by the addition of beef-tea fortified by a little Somatose. In prolonged cases vegetable soups and fruit juice should be allowed, in order to insure the supply of a sufficient quantity of potash salts to the blood. Where there is much tympanites it is well to substitute whey for milk.

It is difficult to justify the conventional strict diet of enteric fever on any grounds other than those of experience. The widely-spread impression that solids are injurious on account of the danger of their irritating the intestinal ulcers, and predisposing to hæmorrhage and perforation, can hardly be defended, for, as we have already seen (p. 431), the intestinal contents, by the time the lower end of the ileum is reached, are always in a fluid form.

In recent years a revolt against the orthodox practice has taken place, and a more abundant diet has been advocated, the extremest supporter of the new view being the Russian physician Bushuyez. The diet which the latter has adopted is certainly an extremely liberal one. The following is the scheme of it :

7 a.m. : Tea and a roll.

8 a.m. : 14 oz. of gruel (oatmeal, barley or wheat) with butter.

9 a.m. : One or two boiled eggs.

10 to 11 a.m. : A glass of milk, a roll, half a cutlet, and a bit of boiled meat.

12 to 12.30 p.m. : A bowl of soup and a little jelly.

3 p.m. : Tea and a roll.

6 p.m. : A cup of soup, a bit of chicken, and milk pudding.

8 p.m. : A roll and milk.

During the night coffee or tea, with milk, is allowed several times.

In 318 cases in which this diet was adopted the mortality was only 8.2 per cent.; not a single case was lost from hæmorrhage, while the general condition of the patient was much better than that of those fed on the orthodox lines. All the patients were allowed to sit up in bed, and many were able to walk a little.

A paper by Dr. Morris-Manges¹ contains a full account of the results yielded by the new diet. The writer himself used a diet consisting of milk, soft-boiled eggs, custard, jellies, chicken, rice, baked potatoes, and strained cereal gruels, in eight cases. He states

¹ *New York Medical Record*, 1900, lvii. 1.

that the stools were always well digested, that the diarrhœa was not increased, and that subsequent emaciation and anæmia were very slight. He had 25 per cent. of relapses, but this, as he points out, is much higher than that found by Bushuyez and others in a much more extended series of cases.

Vaquez¹ in France, Strouse² and Coleman³ in America, and, in this country, Barrs,⁴ Marsden,⁵ and F. J. Smith⁶ also advocate the more liberal diet, and report good results from its adoption.

The present writer's own belief is that here, as in most forms of illness, one must individualize, and that whereas in some cases the patient may be intolerant even of diluted milk, and must be fed exclusively on whey and grape-juice, yet there are many cases in which the administration of semi-solid, or even solid, food is justifiable at an early stage of the disease. In every case, of course, insoluble vegetable articles, such as the skins and pips of fruit, currants, etc., should be rigidly withheld, but such things as lightly-cooked eggs, custards, rusks, milky puddings, bread-sauce, and crisp toast are often quite admissible, and undoubtedly help to maintain strength and nutrition, and to shorten convalescence. If a patient expresses a wish for such foods it is usually safe to conclude that they will not harm him.

Cushing and Clarke⁷ recommend the administration of large quantities of water (a gallon or more in twenty-four hours) in typhoid fever. This is easily managed if given in small quantities at frequent and regular intervals. They find that patients are more comfortable on this mode of treatment, and that toxic nervous symptoms are lessened. They regard it as a valuable adjunct to the cold bath.

2. Disorders of Metabolism.

THE DIETETIC TREATMENT OF DIABETES MELLITUS.

1. Treatment by Restriction of Carbohydrates only.—This method, which was formerly employed in all cases of diabetes, is still applicable in the less severe examples, that is to say, those met with chiefly in elderly persons, in which the amount of sugar excreted is moderate, and in which there is no 'acidosis'—cases sometimes described as diabetes of the 'alimentary' type.

The first thing to be done in such a case is to ascertain the patient's 'tolerance' for carbohydrates, and with that object he

¹ *La Presse Méd.*, 1900, viii. 73.

² *Amer. Journ. of Med. Sciences*, 1909, cxxxvii. 631.

⁴ *Brit. Med. Journ.*, 1897, i. 260.

⁶ *Brit. Med. Journ.*, 1906, ii. 1014.

⁷ *Amer. Journ. of Med. Sciences*, 1905, cxxix. 187.

³ *Ibid.*, Jan., 1912.

⁵ *Lancet*, 1900, i. 90.

should be put upon a diet containing no carbohydrate except that contained in a known quantity of bread. Four ounces of bread may be given in divided quantities throughout the day. If at the end of three days he is found to be still passing sugar, the bread is reduced by an ounce at a time till the sugar disappears. If this happens when he is taking, say, two ounces of bread, that is 'his 'tolerance,' and his permanent diet should contain rather less carbohydrate than that. If, however, there is no sugar excreted on four ounces of bread, then the allowance is gradually increased till sugar appears. Should he, on the other hand, still pass sugar even when bread has been reduced to vanishing point, the case must be regarded as a severe one and not suitable for this method of treatment.

In constructing the permanent diet the patient is allowed the following foods freely:—

All animal foods (*e.g.*, meat, fish, game, eggs, cheese), but *not* liver, sausages, or oysters.

All clear soups.

Unsweetened jellies.

All *green* vegetables (but not peas, beans, lentils, carrots, parsnips, and beetroot).

Asparagus, celery, young rhubarb, tomatoes, cucumber, and mushrooms.

All nuts (except chestnuts); *early* oranges, apricots, and gooseberries may be taken in moderation.

The following foods are forbidden:—

Sugar, sweets, jams and marmalade.

All sweet and dried fruits (especially grapes, bananas, figs, dates, raisins, currants, and prunes).

All farinaceous foods (*e.g.*, rice, sago, arrowroot, tapioca, macaroni, etc.).

Puddings and pastry.

Potatoes.

The following beverages should be avoided:—

Malt liquors, sweet wines, sweetened aerated drinks (*e.g.*, lemonade), liqueurs, and cordials made with sugar (*e.g.*, lime juice).

Fats may be taken in increased amount to replace carbohydrates in the diet, and alcohol, except in the forms indicated above, may be allowed in moderation, especially if the patient is accustomed to its use.

The food which is most missed in such a diet is bread, especially when the patient's 'tolerance' is low. The special 'diabetic' breads are best avoided. Those which are really palatable all contain starch, whilst those which are starch-free are expensive and usually not well tolerated. Starch-free biscuits, however, are useful additions to the diet in moderation. As far as possible, however, the patient should be encouraged to do without bread, and to use vegetables (salads, tomatoes, etc.) in place of it. If, however, he has a fair degree of carbohydrate tolerance, some of his allowance of ordinary bread may be replaced by an equivalent amount of other carbohydrate food if he prefers it. Thus—

- 2 ounces of white bread are equal in carbohydrate to 2 ounces of pea or lentil flour.
- 2 ounces of white bread are equal in carbohydrate to $1\frac{1}{10}$ ounces of rice.
- 2 ounces of white bread are equal in carbohydrate to $1\frac{1}{2}$ ounces of oatmeal.
- 2 ounces of white bread are equal in carbohydrate to $1\frac{1}{2}$ ounces of corn-flour, arrowroot, tapioca, sago, or rice.
- 2 ounces of white bread are equal in carbohydrate to 6 ounces of cooked potato.
- 2 ounces of white bread are equal in carbohydrate to 10 to 15 ounces of the sweeter fruits.

The following table will also help in selecting the most suitable foods :—

APPROXIMATE PERCENTAGE OF CARBOHYDRATES IN SOME FOODS.

<i>Milk Products.</i>		Carrots	10.0	Leeks	5.8
Cow's milk	4.5	" (cooked) ..	3.0	Tomatoes	5.0
Butter-milk	3.3	Turnips	5.0	Vegetable marrow	
Koumiss	1.5	" (cooked) ..	0.6	(cooked)	0.2
Cream	3.0	Radishes	4.6		
Devonshire cream ..	1.5	Beetroot	11.0	<i>Fruits.</i>	
		" (cooked) ..	2.8	Apples and pears ..	12.0
<i>Cereals.</i>		Parsnips	14.0	Stone-fruits	10 to 15
White bread	50.0	" (cooked) ..	1.4	Gooseberries (ripe)	9.0
Oatmeal and rolled		Artichokes	14.6	" (green)	2.0
oats	65.0	" (cooked) ..	4.6	Currants	8.0
Rice	76.0	Onions	6.3	Strawberries	6.0
" (boiled)	40.0			Raspberries	5.0
		<i>Vegetables.</i>		Cranberries	4.0
<i>Pulses.</i>		Cabbage (cooked) ..	0.4	Grapes	15.0
Green peas	16.0	Sprouts	3.4	Melons	7.0
Dried "	55.0	Lettuce	2.6	Bananas	22.0
French beans	7.0	Spinach (cooked) ..	0.8	Oranges (ripe) ..	8.9
Revalenta	65.0	Water-cress	3.7	" (young)	2.0
Soy beans	28.0	Cauliflower	4.7	Pineapples	9.5
Peanuts	17.0	Asparagus	2.9		
		Cucumber	2.1	Nuts	9 to 12
<i>Roots and Tubers.</i>		Rhubarb	2.3	Almonds	10.0
Potatoes	20.0	Celery	3.3	Chestnuts	40.0

Milk should be avoided except in the mildest cases, and cream used in tea and coffee instead. Sugar-free milk,¹ however, is permissible and may be used to make custards, etc.

On such a diet as this many patients with a mild degree of diabetes remain free from sugar and in active health for an indefinite time. They will probably lose weight, but that is no disadvantage, and no attempt should be made to counteract it by giving large quantities of protein and fats.

2. Treatment by Restriction of all the Ingredients of the Diet.—Allen, in America, and Graham, in this country, have independently worked out a new method of treating diabetes, in which not only the carbohydrates but the proteins, and in some cases, also, the fats, are rigidly restricted. The exact *modus operandi* of the method is still disputed, but it is found in practice that, by keeping the patient on as low a level of metabolism as possible, both the excretion of sugar and also the development of 'acidosis' can be controlled. It is sometimes spoken of as treatment by 'alimentary rest,' or, less happily, as the 'starvation' method. It is also described as the 'modern' treatment, in contradistinction to the older method outlined above. This method is suitable for all the more severe cases of diabetes, such as are specially met with in young subjects, and in which acidosis is often a pronounced feature, as well as a high grade of glycosuria.

The details of the diet recommended by Allen and by Graham respectively differ considerably, but both agree in making a large use of vegetables of low carbohydrate value. GRAHAM'S is the simpler, and is sometimes described as the 'vegetable and egg' or 'ladder' diet. The author describes it as follows:²—

'The patient is allowed his ordinary diet on the first day on which he enters hospital with the addition of 600 c.cm. milk and 50 grammes bread unless he is on the verge of coma. The amount of sugar which is passed in this portion of the day is estimated and gives a rough idea of the severity of the disease. Two days' starvation are then given, tea, coffee, meat extract, and as much water as is desired being allowed. Whether the urine is sugar-free or not, the patient is not allowed to fast more than two days at a time. On the third and fourth days the egg and vegetable diet of 5 eggs, 50 grammes butter, and 300 grammes greens is given. If the patient is still passing sugar two more fast days are given, and this is alternated, as a rule, until the urine is sugar-free or the attempt to get it sugar-free has to be abandoned. If the patient is sugar-free 50 grammes of meat are added to the midday meal for two days. On the seventh and eighth days 50 grammes of ham are added for tea and one egg is taken away. On the ninth and tenth days 500 grammes of bacon are given at breakfast and one egg is

¹ Supplied by Messrs. Callard and Co.

² 'Goulstonian Lectures on Glycæmia and Glycosuria,' *Lancet*, May 21, 1921, p. 1062.

taken away. If the patient passes traces of sugar on two successive days he is put back to the bottom of the ladder and made to climb up again. If no sugar is passed 100 c.cm. of milk are given on the eleventh and twelfth days—that is, 4 grammes of sugar. This makes the tea and coffee more palatable. If no sugar is passed 15 grammes of bread—*i.e.*, 8 grammes of sugar—are given in two doses. On the thirteenth and fourteenth days another 15 grammes of bread are added, so that the patient gets four doses of 8 grammes of bread at four meals. It is most important to divide the carbohydrate among as many meals as possible so as to spread the effect of the dose of sugar on the level of the blood sugar as much as possible. If the patient is doing well the bread is increased to 45 grammes, which is enough to keep most patients comfortable. If the amount of aceto-acetic acid is quite small, a mere trace, the butter is then increased in two doses of 25 grammes, watching the effect on the aceto-acetic acid reaction and sugar.

‘This makes a diet of: carbohydrates, 41; protein, 35.5; fats, 167.5; total Calories, 1865, which for a man of 60 kilos is 31 per kilo. The protein is 0.57 per kilo. It is quite true that this represents a considerable degree of under-nutrition, but it seems to be quite enough to enable weight to be maintained and life to be enjoyed. I think that it is wiser not to try to test the tolerance any further at this stage, but at the end of each month, if all is well, the amount of bread can be increased by another 15 or 30 grammes if it can be tolerated. This diet is enough to live on and do light work. If, as often happens, the patient passes sugar when he is tested with 15 or 30 grammes of bread, he is put back and kept at a lower level for a further period.’

The addition of alcohol to the diet, up to the equivalent of two ounces of absolute alcohol daily, is often helpful. Graham adds that the treatment of the patient who passes sugar as soon as food is given, in spite of repeated fasts, is very difficult. Unless all hope is abandoned of improving the condition it is better to persevere with a very small amount of vegetables, protein, and fat, adding a certain amount of alcohol. The outlook in a long-standing case of this severity is very bad, but in an early acute case the treatment should be persevered with for a considerable time, as the acute case sometimes makes a surprisingly good recovery.

In carrying out the low-diet principle by ALLEN's method one must begin, if there is acidosis, by putting the patient for two days on a ‘fat-free’ diet. That used by Leyton¹ is as follows:—

Breakfast.—An egg, lettuce (4 ounces), coffee (12 ounces), milk (2 ounces).

Lunch.—Clear soup (8 ounces), lean meat (2 ounces), cooked cabbage (8 ounces).

Tea.—Tea (12 ounces), milk (1 ounce), radishes (2 ounces).

Dinner.—Clear soup (8 ounces), white fish (2 ounces), an egg, stewed celery (8 ounces), an orange.

¹ ‘The Modern (Allen) Treatment of Diabetes Mellitus’ (London: Adlard and Son and West Newman, Ltd.), second edition, 1918, p. 21.

After these two days the patient is kept in bed and an attempt made to get rid of the sugar by starvation, the diet being restricted, until 24 hours after sugar has disappeared, to weak tea and coffee and clear beef-tea. Alcohol may also be allowed if the patient is accustomed to it.

The fast is continued until the urine has been free from sugar for 24 hours. After this increasing amounts of vegetables of low carbohydrate value are given daily, the protein intake being meanwhile kept low, until the carbohydrate tolerance is ascertained. When this stage has been reached the protein is rapidly increased until about 1·5 grammes is being taken per kilo of body weight, and an amount of fat is then gradually added sufficient to raise the energy value of the diet to about 20 to 30 Calories per kilo.

In carrying out these principles in practice, the daily estimation of the protein, carbohydrate, and fat in the diet, as well as of its Calorie value is essential. In order to facilitate this tables have been constructed, but for these and for the clinical details of the management of such cases special works must be consulted.¹ The method, it must be pointed out, is one which makes considerable demands both upon doctor and patient, and unless the hearty co-operation and obedience of the latter can be counted upon it is wiser not to embark upon it at all.

¹ See Allen and Goslin, 'The Diabetic Manual,' second edition (Philadelphia and New York: Lea and Febiger), 1919; Leyton, *op. cit.*; Spriggs' article on Diabetes Mellitus in 'An Index of Treatment' (John Wright and Sons, Ltd.), 8vo. edition, 1921.

CHAPTER XXVIII

THE PRINCIPLES OF FEEDING IN DISEASE (*continued*)

THE DIETETIC TREATMENT OF OBESITY.

THE occurrence of obesity is almost invariably an indication of a disproportion between the intake of potential energy in the form of food and the output of actual energy in the form of work. Sometimes the fault lies in an unduly large income, sometimes in too small an expenditure; not unfrequently both factors co-operate. There would seem, however, to be another, but very limited, group of cases, in which, owing to some inherent lack of vital power in the cells of the body, fat is able to accumulate even in the absence of any excessive intake of food. This may explain some of the cases in which patients become fat even although they are very moderate eaters. There is reason to believe, however, that this is a very rare event, and that in the majority of cases in which it is alleged to occur, the patient is really the victim of self-deception.¹

It is obvious from these considerations that the proper treatment of obesity must consist either in a reduction in the total number of Calories of energy supplied in the food, or in an increase in the output of energy in the form of work, or in a combination of these methods.

An increased expenditure can be achieved by the use of suitable muscular exercises, but that method of treatment does not concern us here, and we may now direct our attention to the best means of diminishing the intake of energy in the form of food. And first one may ask, **Which chemical ingredient of the food is it most important**

¹ See Hirschfeld, 'Ueber den Nahrungsbedarf der Fettleibigen,' *Berliner Klinik*, April, 1899, Hft. 130, 1-22; also Hoffmann, Leyden's 'Handbuch der Ernährungstherapie,' p. 540; Von Noorden, 'Die Fettsucht,' p. 24, Vienna, 1900; and Rubner, 'Beiträge zur Ernährung im Knabenalter,' Berlin, 1902. The obesity of young subjects, however, seems sometimes to be due to a congenital peculiarity of metabolism, and not to any excessive consumption of food. Such cases do not lend themselves to dietetic treatment.

to reduce—the proteins, carbohydrates, or fats? Physiological investigation has shown that all of these ingredients *may* serve as sources of fat in the body if consumed in excess, but the risk of proteins being converted into fat seems to be very small. As regards the relative dangers of an excess of carbohydrates or fats in the food, classical authorities on the subject are not altogether agreed, and, as we shall see immediately, schemes of diet for the obese have been drawn up, in some of which the carbohydrates have been specially restricted, while others are characterized by a limitation of fats.

The progress of research into metabolism in obesity, however, has shown that the question is, after all, and as far as the mere storage of fat is concerned, one of indifference. The only essential point is to reduce the total number of Calories supplied in the form of food, and whether this should be accomplished by limiting the carbohydrates or the fats, or both, is purely a matter of convenience, and one which must be decided chiefly by the tastes and habits of each individual patient.¹

The next problem which presents itself, then, is, **To what extent should the total number of Calories in the diet be reduced?** Here, again, no hard-and-fast rule can be laid down. In some cases, such as in the very young, in whom probably a marked congenital tendency to the disease exists, it is difficult to keep the undue formation of fat in check at all. In others, such as the very old, it is probably unwise even to make the attempt, while in particular instances—for example, those in which the chief deposit of fat is in the abdomen—treatment is always peculiarly difficult. In an average case, however, such as is most commonly met with in the later periods of middle life, one must be guided mainly by the degree to which the obesity has developed, and in judging of this it is always better to go by the general appearance of the patient rather than by tables of height and weight.

Following the teaching of Von Noorden, and assuming that an average man of this age requires to be supplied with from 2,500 to 3,000 Calories of energy daily to meet his current expenditure in heat and work, one may divide cases into three groups:

1. Those in which it is merely necessary to reduce the diet by one-fifth, which means the supply of 2,000 Calories. This can best be done by cutting out sugar by reducing the supply of fat and carbohydrates, and by restricting the consumption of alcohol.

This plan is only likely to be successful if it can be combined with

¹ See Von Noorden, *op. cit.*

a free use of muscular exercise, and in any case the loss of weight under it can only be very slow.

2. In severer cases the diet may be reduced two-fifths, which means supplying only 1,500 Calories. Here it will be necessary still further to reduce the amount of fat in the diet, and to limit the consumption of bread; and in this case also the loss of weight is apt to be slow, unless the patient can at the same time take at least a moderate amount of active exercise. Von Noorden states that he prefers this scheme to any other, because, while it usually gives good results, it is never attended by any disagreeable consequences. He specially recommends it—

(a) In patients who are being treated at home, and are continuing to follow their usual occupation.

(b) In patients who can go into the country, and take a moderate amount of exercise without requiring medical supervision.

(c) In those for whom, owing to the presence of visceral complications, a rapid 'cure' might be dangerous.

(d) As the habitual diet in advanced cases in which periods of greater restriction are being observed.

3. The third degree of diet is that in which the total Calories supplied are reduced three-fifths—*i.e.*, to about 1,000 to 1,500 per day.

This group includes all the classical 'systems' of diet for obesity, as is shown by the following table:

<i>System.</i>	<i>Protein. Grammes.</i>	<i>Carbohydrate. Grammes.</i>	<i>Fat. Grammes.</i>	<i>Calories.</i>
Banting	172	81	8	1,100
Oertel (maximum) ..	170	120	45	1,600
„ (minimum) ..	156	75	25	1,180
Ebstein	102	47	85	1,300
Hirschfeld (maximum)	139	67	65	1,400
„ (minimum)	100	50	41	1,000
Von Noorden	155	112	28	1,366

Some of these demand a word of description.

Banting System.—This scheme of diet was first popularized by the writer whose name it bears,¹ although it had previously been recommended in France by Léon.

Banting suffered from an extreme degree of obesity, so great, he tells us, as to render him unable to tie his own shoe, and to compel him to go downstairs backwards. Having consulted various physicians without success, and having tried the effects of violent

¹ See 'A Letter on Corpulence addressed to the Public,' by William Banting London, 1863.

rowing exercise and a course of Turkish baths, he was finally advised by an aural surgeon, Dr. Harvey, to abstain from bread milk, butter, sugar, and potatoes, 'which had hitherto been the main and, as he thought, innocent elements of his existence,' and to adopt instead the following diet :

Breakfast.

- 4 to 5 ounces of beef, mutton, kidneys, broiled fish, bacon, or any cold meat except pork ; a large cup of plain tea, and a little biscuit or 1 ounce of toast.

Dinner.

- 5 to 6 ounces of any lean meat or fish, any vegetable except potatoes, 1 ounce of dry toast, some fruit out of a pudding, any kind of poultry or game, and 2 to 3 glasses of good claret, sherry or madeira.

Tea.

- 2 to 3 ounces of fruit, a rusk or two, and a cup of plain tea.

Supper.

- 3 to 4 ounces of meat or fish as at dinner, and a glass or two of claret.

For a 'night-cap' he was allowed a tumbler of 'grog' without sugar, or a glass or two of claret or sherry.

On this regimen Banting lost 35 pounds of weight in thirty-eight weeks, which is not surprising, considering that his diet hitherto had consisted of bread-and-milk for breakfast, or a cup of tea with plenty of sugar and milk, and buttered toast ; meat, beer, much bread (of which he was always very fond), and pastry, for dinner ; a tea of the same composition as breakfast, and a fruit tart or bread-and-milk for supper. He found sugar the most fattening of all foods, 5 ounces of it in a week causing his weight to rise 1 pound ; and he calls milk, sugar, beer, and butter 'human beans,' because they have the same effect in the human subject that beans have in the case of the horse, and he regards these articles as 'the most insidious enemy an elderly man with a tendency to corpulency can possess, though eminently friendly to youth.' He adds : 'I can conscientiously assert that I never lived so well as under the new plan of dietary.'

It will be observed that the chief chemical characteristic of the Banting system is the great predominance of proteins in the diet, and it has been asserted, though with only a limited degree of truth, that owing to this fact one is more likely to insure a loss of body fat alone on it, and to prevent any inroads into the muscular tissues, than by any other plan.¹

¹ For a discussion of this subject see Dapper, *Zeit. f. Klin. Med.*, 1893, xxiii 113, and Von Noorden, *op. cit.*

Be this as it may, the system has certainly the advantage of simplicity and of being easily regulated, and on this account it is likely to retain its popularity. It should be pointed out, however, that the large excretion of nitrogen which such a diet entails is apt to throw a severe strain upon the kidneys, and for that reason it is well always to investigate the state of these organs before embarking upon the treatment.

The chief characteristic of **Oertel's system**,¹ which has been largely popularized in Germany, though with some slight modification, by Schweningen, is that he restricts the consumption of fat more than that of carbohydrates, and at the same time lays great stress on limiting the amount of fluid in the diet. To the discussion of the latter point we shall return later, but at present the following may be taken as a type of his system. It is adapted, of course, to German habits:

First Breakfast.

1½ ounces of white bread, 2 eggs, a large teacupful of coffee with 1 ounce of milk and 1 lump of sugar, and (in some cases) ½ ounce butter.

Second Breakfast.

2 ounces of lean meat, ¾ ounce of coarse bread, 3½ ounces of light wine or clear soup.

Dinner.

5½ ounces of roast beef with salad or green vegetables, 3½ ounces of pudding and fruit, a tumblerful of light wine, and (in some cases) 1 ounce of bread.

Afternoon.

A small cup of coffee as at breakfast.

Supper.

½ ounce of caviare, 5½ ounces of chicken or game, ½ ounce of cheese, ¾ ounce of coarse bread, a tumblerful of water or light wine.

Ebstein² modified Banting's diet by increasing the proportion of fat and giving less protein, as follows:

Breakfast.

A large cup of tea without milk or sugar, 2 ounces of bread with plenty of butter.

Dinner.

Soup, 4½ to 5½ ounces of meat with fat sauce, green vegetables, fresh fruit, 2 to 3 glasses of light wine.

Afternoon.

Tea as at breakfast.

Supper.

Tea, one egg, fat roast meat or ham, smoked fish, about 1 ounce of bread with plenty of butter, a little cheese, and fresh fruit.

¹ Oertel, 'Twentieth Century Practice,' ii. 625.

² 'Corpulence and its Treatment on Physiological Principles' (translated from sixth German edition); Wiesbaden and London, 1884.

Ebstein gives the following summary of his plan: 'The permission to enjoy certain succulent things, always, of course, in moderation, as, for instance, salmon, pâté-de-foie-gras, and such-like delicacies, reconciles the corpulent gourmet to his other sacrifices. These consist in the exclusion of the carbohydrates. Sugars, sweets of all kinds, potatoes in every form, I unconditionally forbid. The quantity of bread is limited at most to 3 or 3½ ounces a day, and of vegetables I allow asparagus, spinach, the various kinds of cabbage, and the legumes. Of meats I exclude none, and the fat in the flesh I do not wish to be avoided, but rather sought after. I permit bacon-fat, roast pork and mutton, and kidney-fat, and when no other fat is at hand I recommend marrow to be added to the soups. I allow the sauces as well as the vegetables to be made juicy, as did Hippocrates, only for his sesam-oil I substitute butter.'

Hirschfeld's diet¹ resembles that of Ebstein very closely:

Breakfast.

2 ounces of bread, and coffee without sugar or milk.

Forenoon.

2 eggs.

Dinner.

Soup with 2 ounces of rice (weighed uncooked), 8 ounces of lean meat boiled or roasted with a little fat.

Afternoon.

Black coffee.

Supper.

2 ounces of cream cheese, 4 ounces of bread, ½ ounce of butter.

Von Noorden² gives a large number of small meals, and restricts fats more than carbohydrates:

8 a.m.: 3 ounces of cold lean meat, 1 ounce of bread, a cup of tea or coffee with a spoonful of milk, but no sugar.

10 a.m.: 1 egg.

Noon: A cup of strong soup without fat.

1 p.m.: A small plate of clear soup (à la Julienne or à la jardinière), 5 ounces of lean meat or fish, 3½ ounces of potatoes, green vegetables, 3½ ounces of fresh fruit.

3 p.m.: A cup of black coffee.

4 p.m.: 7 ounces of fresh fruit.

6 p.m.: A glass of skimmed milk.

8 p.m.: 4½ ounces of cold lean meat with pickles, 1 ounce of Graham bread, 2 to 3 spoonfuls of fruit cooked without sugar.

He also allows two glasses of wine a day.

It will be observed that all of these systems, seeing that they fall

¹ 'Beiträge zur Ernährungslehre des Menschen,' *Virchow's Archiv.*, 1888, cxiv. 301; and 'Ueber den Nahrungsbedarf der Fettleibigen.' *Berliner Klinik*, Hft. 130, 1899.

² *Op. cit.*, p. 122.

short by at least 1,000 Calories of the number requisite to meet the outgoings of the body, must be regarded as **starvation methods of treatment**.¹ For this reason it is never safe to carry them on for more than a few weeks at a time, during which the patient must be under strict supervision, and any symptoms of weakness or heart failure carefully watched for.

As regards the **relative advantages of the different methods**, a good deal of difference of opinion exists, and some patients will be found to prefer one plan, some another.

Ebstein specially recommended the inclusion of a considerable amount of fat in the diet, on the ground that, while it does not tend to the production of fat more than its equivalent of carbohydrate, it has a greater 'satisfying' power, and tends to allay feelings of hunger. It may be doubted, however, as Von Noorden has pointed out, whether this is really true of such quantities of fat as it is safe to allow, while, on the other hand, the greater bulk of carbohydrate food certainly tends to produce a feeling of satisfaction.

The point, however, is really one of indifference. Some patients stand a limitation of fat better than that of carbohydrates, whereas in the case of others the reverse holds good, but as long as the total number of Calories in the diet is kept low fat must inevitably continue to be lost from the body.

Whether or not it is advisable to restrict the amount of fluids in the diet, and if so to what extent, we shall proceed to discuss immediately.

ON THE USE OF PARTICULAR ARTICLES OF FOOD IN OBESITY.

In drawing up a scheme of diet for the obese, it is well to avoid too great variety, for that always tends to increase appetite. For the same reason, all spices, condiments, and other articles that increase the desire for food, must be used very sparingly.

The following list of the Calorie value of some of the commoner articles of food may be of assistance in enabling one to arrive at some idea of their relative suitability as articles of diet for the corpulent. (See also the tables on pp. 7, 426.)

¹ This statement is hardly true for all individuals. The writer, for instance, has recently had a patient—a lady of 12 stones—who lost no weight on Ebstein's diet for five weeks, although the amount of energy yielded by her daily supply of food was less than 1,200 Calories. Later on she began to lose weight at the rate of a pound a week.

<i>Article.</i>	<i>Calorics.</i>
2 ounces of cheese.. .. .	224
1 ounce of butter (enough to cover three or four slices of bread) ..	208
A helping of cooked lean meat (4 ounces)	196
A tumblerful of milk	140
A moderately thick slice of bread (2 ounces)	138
" " " and butter	208
A heaped dessert-spoonful of milk pudding	110
One egg	70
One medium-sized potato (2 ounces)	45
An ordinary lump of sugar	16

The use of sugar should be avoided altogether, and saccharin employed as a sweetener instead. Visible fat should be removed from meat, and the richer meats, such as pork, goose, etc., and the fatter fishes, such as mackerel, eel and salmon, interdicted. Milk and its products should only be used in moderation, and puddings must be unconditionally forbidden. Bread, also, is a very dangerous food, but as it can hardly be dispensed with altogether, it should only be allowed in weighed quantities.¹ It is well, too, to select the coarsest sorts of bread, which contain much indigestible bran, such as Graham bread ; for a given bulk of these yields much less nutriment to the body than an equal weight of fine bread. Potatoes, as the table shows, are not nearly so dangerous as bread, and may often be allowed in moderation. It is better to avoid the other roots and tubers, but green vegetables and mushrooms may be freely permitted, and their great bulk has the advantage of producing a feeling of satisfaction. Dried fruits as containing much sugar must be strictly forbidden, but fresh fruit may be allowed in moderation, and, if stewed, should be sweetened with saccharin. All made dishes, thick soups, sauces and pastry must be cut out of the menu, as they are subtle vehicles for the conveyance of much fat and starch into the body.

The arrangement of the meals must be regulated to a large extent by the habits of the patient. Where it is feasible, most authorities seem to prefer that they should be small and frequent, as the total amount of food consumed is thus more easily kept under control.

BEVERAGES IN OBESITY.

The first question to be settled regarding the use of beverages in obesity is whether or not it is important to **diminish the total amount of fluid** in the diet in that disease. The restriction of fluids was first advocated by a French military surgeon—Dancel—in a book

¹ Some of the partially or entirely starch-free breads and biscuits sold by the makers of diabetic foods may be used instead of ordinary bread.

published in 1863.¹ He had observed the influence of water and watery fluids in producing abdominal development in the horse, and he made reduction of fluids one of the main principles in the regimen which he drew up for corpulency. The principle was subsequently adopted by Oertel and Von Schweningen, and attained through their advocacy a very considerable degree of popularity.

Exact observation,² however, has now shown that the influence which the amount of water in the diet exerts upon the production or loss of fat in the body is very small in amount and uncertain in degree, and that, as a matter of fact, fat people are less affected by a restriction of fluids than are lean.

Dancel restricted the intake of fluids to 7 to 14 ounces per day. Oertel allowed a daily maximum of 2½ pints, and Von Schweningen of about 3 pints, but the latter made a strong point of fluids not being taken along with solids, but rather between meals.

The opinion of most authorities at the present time³ seems to be that the restriction of fluids has, at best, only an indirect influence. In the case of some patients the interdiction of fluids at meals interferes with appetite, and so results in less solid food being consumed. In such cases the method may be of value, but where no such result ensues, the loss of weight which results is only temporary, and due to a diminution of the body fluids. It is probable, too, as Yorke Davies has pointed out,⁴ that one reason why restriction of fluids has given better results on the Continent than one sees in this country is, that in Germany, at least, restriction of fluids is very often synonymous with restriction of beer.

The whole question, indeed, is to be regarded as one affecting the *technique* of feeding rather than the physiological principles upon which the dietetic treatment of obesity is founded.⁵ Von Noorden concludes that restriction of fluids should only be insisted upon when the following indications are present:

1. *Weakness of circulation.* A dry diet is advisable here for the sake of the heart, apart altogether from the obesity.
2. *At the commencement of many 'cures.'* Here the initial loss of weight which the restriction of fluids brings about is calculated to make a great mental impression on the patient.
3. *In cases where the restriction results in a diminished appetite for fat-forming foods.*

¹ See also *Bull. de Therap.*, 1864, lxvii. 44.

² Dennig, *Zeit. f. Diät. und Physik. Therap.*, 1899, ii. 292.

³ See a discussion on obesity reported in the *Verhandl. d. 4ten Cong. f. Inn. Med.*, 1885.

⁴ 'Foods for the Fat,' p. 26.

⁵ See Von Noorden, *op. cit.*, p. 124 *et seq.*

4. *Where sweat excretion is excessive.* He considers that the total amount of fluid allowed should not be reduced below $2\frac{1}{2}$ pints per day.

Where a Banting or any other very nitrogenous diet is being adopted, the restriction of fluids is to be avoided, as being opposed to the free elimination of the products of nitrogenous waste.

Of the different sorts of beverages in common use, water and the saline mineral and table waters may be regarded as harmless; but the sweetened effervescing waters, such as lemonade, should be avoided. Tea and coffee may be freely permitted, if taken with little milk and no sugar. Cocoa is often forbidden, but the amount of nutriment which an ordinary cupful of it contains is so small as to be hardly appreciable. In many people, also, it has the advantage of lessening the appetite for solid food.

Alcoholic beverages should be avoided as far as possible, for alcohol is, as we have seen, a direct sparer of fat. If a small allowance is indicated on other grounds—*e.g.*, feebleness of heart—a dry natural wine should be selected, or its alcoholic equivalent of well-matured spirit freely diluted with water. All strong and sweet wines, liqueurs and malt liquors should be interdicted.

FATTENING DIET.

In the previous section we have dealt with the dietetic methods of reducing fat. We have now got to consider the means at our disposal for increasing it.

Generally speaking, any excess of food which is supplied to the body beyond the amount required to meet the current outgoings of energy in the form of heat and work will be stored up in the form of fat. One does, however, meet with cases in which, owing probably to some failure of assimilative power, it is found to be very difficult to achieve the laying on of fat, even although a considerable surplus of food is supplied, but as a rule one may say that in order to fatten the body one has merely to insure the supply of an excess of food.

It will be obvious that one important means of bringing about such a surplus of income over expenditure is to diminish the outgoings of energy from the body. For this reason, rest, more or less complete, is always an important aid in cases in which one wishes to fatten.

As regards the constituents of the food which are most important in respect of fattening properties, it may be said that fat itself, owing to the ease with which it can be stored, takes the first place. It has

been calculated by Rubner that 100 parts of fat, 248 of carbohydrate, and 313 of protein, are equivalent in fat-forming power. Whether all forms of fat are equally valuable in this respect must be left undecided, but it is probable that some fats produce a more stable kind of adipose tissue than others.¹

When one comes to the actual construction of a fattening dietary, however, due attention must be paid to the powers of the digestive organs, and for that reason it is better to see that carbohydrates and fats are both abundantly represented, rather than to trust to one or other of them alone. Munk is of opinion that, in order to insure the laying-on of fat, one should supply 90 to 100 grammes of fat, 100 to 110 of protein, and about 500 of carbohydrate, daily.

The permanent enrichment of the body in protein (practically in muscular tissue and blood) is very much more difficult of accomplishment than the mere deposition of a certain amount of fat. So great is the tendency for nitrogenous equilibrium to assert itself that it is almost impossible to bring about a storage of protein in the body² unless (1) a considerable amount of muscular exercise is taken at the same time, or unless (2) there has been a previous wasting of the muscles, such as occurs during acute disease.

In the former case the bulk of the muscles exercised can, up to a certain limit, be increased; in the latter the normal muscular development can be again attained. The one process occurs during training, the other during convalescence. In both protein is stored up.

In practice the storage of protein can be accomplished, granted the presence of one or other of the above conditions, either by increasing the actual amount of protein in the diet or by raising the proportion of protein-sparers. Weight for weight carbohydrate is, it will be remembered, a more powerful protein-sparer than fat; but here, again, in actually constructing the dietary it is better to avail one's self of both ingredients.³

Practically, then, it comes to this, that where one wishes to lay on fat only, one should increase the proportion of fat and carbohydrate

¹ See Weir Mitchell, 'Fat and Blood,' p. 25.

² For a discussion of this subject see Rosenfeld, 'Die Bedingungen der Fleischmast,' *Berliner Klinik*, 1899, Hft. 127, 1-28. In a more recent paper by Kauffmann ('Der Gegenwärtige Stand der Lehre von der Eiweissmast,' *Zeit. f. Diät. und Physik. Therapie*, 1903, vii. 355), the whole question is carefully reviewed, and the conclusion arrived at that some protein probably *can* be laid up in the body, and that this may be accomplished either by an increase of the protein in the food or by supplying a larger amount of protein-sparers. The former method is preferable, if one does not wish to increase the fat in the body at the same time.

³ See Wicke and Weiske, *Zeit. f. Physiolog. Chem.*, 1895, xxi. 42, and 1896, xxii. 137.

in the food, laying, perhaps, greater stress on the former; but where one wishes to lay on protein, the proportion of that ingredient in the food should be increased as well, and prominence given to the increase of carbohydrate rather than to that of fat.

A fattening diet is wanted in three chief sets of conditions: (1) In convalescence from acute illness; (2) in wasting diseases, such as tuberculosis; (3) in some nervous disorders, of which neurasthenia may be regarded as the type.

In **convalescence** the waste of protein and fat which the preceding illness has entailed must be made good. Out of respect, however, to the debilitated digestive powers of such a patient, one must proceed with caution. There is reason also to believe that the metabolic conditions of fever continue for a day or two after the temperature has fallen, and on that account some observers advocate the continuance of the fever diet for three days after the pyrexia has ceased. One can then begin to thicken the patient's beef-tea, soups, and milk with cereal flours, and to add other farinaceous foods to the diet. Many of the patent malted foods may be usefully employed here. The increase of protein may be accomplished by the addition of pounded meat to soups in the form of purées, and one may gradually pass on to the administration of the more easily digested forms of animal food, such as chicken, fish, and eggs. Jellies are also agreeable to the convalescent, and, along with custard or light milk puddings, are pleasant forms of protein-sparing food. The enrichment of the diet in fat may be conveniently deferred till later, and should be accomplished by the free use of cream, butter, bacon and suet, or, if these cannot be compassed in sufficient quantity, one may have recourse to cod-liver-oil (see also p. 562).

One of the simplest methods of enriching the diet in wasting diseases is by adding to it a certain quantity of milk. There is frequent opportunity in cases of phthisis of observing the good effects of adding 2 or 3 pints of milk to the ordinary diet, 3 pints representing an addition of about 1,000 Calories to the value of the diet. It can be taken both as a beverage with the usual food and also between meals.

Fat seems to be of special value in the diet of tuberculosis, and by the use of the more easily digested forms of it, such as butter, bacon, pork, salad-oil and cream, one has usually not much difficulty in persuading patients to take enough of it, even when, as is not unfrequently the case in phthisis, a considerable natural repugnance

to fat exists. Smith¹ recommended that phthisical patients should take the following amount of fat daily :

As milk	2½ ounces.
„ butter	2 „
„ bacon	2-4 „
In meat	1½ „
As salad-oil	1 ounce.
„ suet in puddings	¼ „
Cream <i>ad lib.</i>	

Recently, however, there has been manifest a reaction amongst those best qualified to judge against the indiscriminate stuffing of tuberculous patients with fatty and carbohydrate foods, and a recognition of the value and importance of an increased supply of protein, or, in practice, of a diet containing plenty of meat.² Such a diet seems to increase the richness and bactericidal power of the blood; it stimulates leucocytosis, and helps to replace the waste of muscular tissue which is such a marked feature in phthisis. Bardswell and Chapman, who have made a special study of the dietetics of phthisis, recommend for a phthisical male patient who is not doing any work a diet containing about 150 grammes of protein, 150 grammes of fat, and 250 grammes of carbohydrate, with a Calorie value of 3,000.

For women the standard should be somewhat lower, viz., protein 126 grammes, fat 150 grammes, carbohydrate 220 grammes, with a Calorie value of 2,814. The following actual diets conform to these standards :

Article of Food as Served.	Amount Prescribed.	
	For Men.	For Women.
Milk	1500 c.c.	1500 c.c.
Bread	180 grammes.	135 grammes.
Porridge	120 „	120 „
Butter	45 „	45 „
Breakfast meat, such as bacon, fish, etc.	30 „	30 „
Ordinary meat	180 „	150 „
Pudding	300 „	180 „
Vegetables	q.s.	q.s.

¹ *Lancet*, 1864, i. 432.

² See Forbes Ross, 'Meat Albumin Dietary in the Treatment of Tuberculosis,' *Brit. Med. Journ.*, 1901, ii. 1061; Bardswell, Goodbody, and Chapman, 'On the Effects of Forced Feeding in Cases of Pulmonary Tuberculosis,' etc., *ibid.*, 1902, i. 449; 'Dietetics in Tuberculosis,' Proceedings of the Royal Society, B, lxxx. 151; Galbraith, 'The Dietetic Treatment of Pulmonary Tuberculosis from the Point of View of its Hæmatology and Histopathology,' *ibid.*, March 14, 1903; Lloyd Smith, 'Diet in Phthisis,' *Lancet*, 1903, ii. 1015; and Woodcock and Ruston, 'Food Values in Tuberculosis,' *ibid.*, October 23, 1920.

The exact amount and constitution of the diet in each case should be fixed after due consideration has been given to the activity and extent of the disease, the amount to which the patient's weight is below his normal, his digestive capacity, and, to some extent, his personal dietetic likes and dislikes, but one should aim at making good lost weight at the rate of 1 to 2 pounds per week. When the patient has once regained his normal weight or a little more, the diet should be reconstructed more upon the lines of what would be suitable for the same person in perfect health, and if active exercise or muscular work is being performed, the amount of fat and carbohydrate in the diet should be increased.

Anorexia in phthisis is to be met by a change in hygienic surroundings, by the use of bitters, by frequently varying the menu, by giving the food in a more fluid form, and by eliminating the more bulky and less nutritive articles—*e.g.*, porridge, green vegetables, etc. The necessary protein in such circumstances can be got in by fortifying fluid foods with one of the soluble casein preparations or by adding it to puddings; fat can be taken in the form of cream and sugar as grape sugar, lactose, lemonade, etc.

When fever exists, the food should be given as far as possible in apyrexial intervals or after the temperature has been artificially reduced by sponging. If the digestive power is good, an effort should be made to maintain the standard diet in spite of the fever, but if this proves impossible, the diet must be constructed on the same lines as for anorexia.

The method of feeding up **neurasthenic patients** has become widely known under the title of the Weir Mitchell Treatment or Rest Cure. The general management of such cases cannot be fully described here, but some points connected with the diet which form so important a part of the plan must be mentioned.

It is usual to begin with milk alone, given quite fresh and perfectly skimmed. The milk should be sipped slowly, it should be warm, and from 40 to 80 ounces should be given daily in equal quantities every two hours. Various methods of varying the flavour of the milk are described on p. 131. After two or three days, some of the milk may be thickened with farinaceous foods (arrowroot, cornflour, groats, one of the numerous patent preparations, etc.), and as digestive power improves, lightly cooked eggs, underdone meat, fish, chicken, game, sieved potato, and bread-and-butter may be gradually added until the patient is taking three large meals a day with from 3 to 5 pints of milk and perhaps a gill of cream and an

ounce of malt extract in addition. The total fuel value of such a diet may in some cases exceed 10,000 Calories.

The food should be plain, appetizing, and well cooked, the chief meal being in the middle of the day, while the evening one is lighter. Part of the milk may be taken with the meals, the rest between them.

In all cases in which a large amount of food is being administered, the use of alcohol, in some form or another, will often be found a great help. Especially is this the case when the diet is very rich in fat. The safest guide to its use is the state of the appetite and digestion. Where these are improved by its administration, it does good. The form to be selected is largely a matter of taste, but a sound red wine, such as burgundy, is perhaps most generally useful, or, if a malt liquor be preferred, good bottled stout.

THE DIETETICS OF GOUT.¹

Unfortunately, chemical pathology is not yet in a position to furnish us with very clear indications as to the best diet for the gouty. In spite of all the work which has been done upon the subject, we are still, it must be confessed, very much in the dark as to the relations of uric acid to general metabolism and to the gouty state. It is becoming more and more clear, however, that, in mammals at least, uric acid is derived mainly, if not entirely, from the decomposition of nucleins either contained as such in the food, or produced by the disintegration of the body cells. Uric acid from the first of these sources may be conveniently described as 'exogenous uric acid,' while the fraction produced in the body may be designated as 'endogenous.'

While the nucleins of the food are the main, they are not the exclusive, source of the exogenous uric acid. Part of it is also derived from such substances as caffeine and from free 'purins' contained in the food. Further, the whole of the uric acid derived from the food does not appear in the urine as such. Part of it is converted in the body into urea and other compounds. The fraction so changed varies from one-quarter to one-half of the total possible yield, but the amount is very constant for different foods, and appears to vary but little in different individuals.

The chief fluctuations in the amount of uric acid in the urine can be explained by variations in the amount of uric acid yielders (purins) contained in the food; the endogenous fraction, on the other hand, seems to be remarkably fixed, but as to its exact seat and mode of formation, and the conditions which control it, we have still much to learn.

¹ For a full discussion of this vexed question, see a paper by A. E. Garrod ('The Dietetic Treatment of Gout'), *Lancet*, June 28, 1913.

Those who believe that uric acid is the *fons et origo* of the gouty state have therefore concentrated their attention upon limiting the intake of uric acid formers in the food, and recommend the adoption of a 'purin-free' diet. Such a diet is described in detail elsewhere (p. 545), but the writer would only say here that, although it undoubtedly gives good results in some gouty persons, it is by no means suited to all, as its prolonged use is apt to lead to impairment of the general health, and particularly of the digestive capacity.

Nothing is more certain, moreover, than that a patient may still suffer from gout, even although the substances capable of yielding uric acid are reduced in the diet to a minimum. For we have still the endogenous production of uric acid to deal with, and about the influence of diet on such production we know almost nothing. Nor does accumulated clinical experience afford as much help as one might expect, for the opinions of different writers on the subject, as so often happens, are exceedingly conflicting, and a system which suits one patient does not necessarily agree with another. On the whole, the belief seems to be gaining ground that quantity must be attended to quite as much as quality, and that the best diet for the gouty is a spare one, composed of simple ingredients, containing only a moderate amount of carbohydrate and fat, and in which not too much of the protein is derived from animal sources. In the light of the above facts, it might be well to add that, so far as is compatible with healthy nutrition, the animal ingredients should consist mainly of milk and eggs; certainly meat should not be taken oftener than once a day.

The dietary usually prescribed for gouty patients at Carlsbad is based upon these principles, and is as follows¹: Breakfast: weak tea with cream, biscuits (2 to 4 ounces), butter ($\frac{1}{2}$ ounce), two soft-boiled eggs. Dinner: soup, either clear or with pearl barley or rice (1 ounce); fish—trout, pike, or perch ($3\frac{1}{2}$ ounces)—with melted butter, lemon-juice, and potatoes (2 ounces); roast veal ($3\frac{1}{2}$ ounces) or mutton cutlets or roast fowl, spinach, cheese (1 ounce), stewed fruit ($3\frac{1}{2}$ ounces), bread (5 ounces). Supper: soup or milk or weak tea with milk, biscuits, lean bacon, or one or two eggs, jam. Beverage at dinner and supper: water, mineral water, $\frac{1}{2}$ pint of light claret with water or two tablespoonfuls of whisky with a half-bottle of mineral water.

It is important to remember, however, that there is no routine plan which is suitable in all cases. The state of the patient's nutrition and digestive and excretory organs may necessitate modifications of the diet in various directions, as may also the presence of complications.

¹ 'The Treatment of Gout in Carlsbad,' by Dr. B. London (*Practitioner*, 1903, lxxi. 161, 320).

BEVERAGES IN GOUT.

What he drinks is, to the gouty man, quite as important as what he eats. Tea, coffee and cocoa are certainly sources of uric acid, and may therefore require to be avoided. Experience also shows that the free consumption of alcohol is harmful, and, if possible, the patient should try to live without it. Too often, however, this is a counsel of perfection, and in that case a sound natural wine, which may be taken with some alkaline mineral water, is the best beverage to select. The stronger wines are dangerous, both on account of the large proportion of alcohol which they possess, and also because they are apt to contain sugar, which is prone to excite dyspepsia in the gouty, even if it has—a point which is still *sub judice*—no influence on the production of uric acid itself. Champagne is also injurious, and so, too, is bottled cider, though ‘rough’ cider and dry sherry usually agree well. It is the fashion to recommend whisky to gouty people, and to this course there can be no objection, provided it be taken well diluted, and the quantity limited to 2 ounces a day. It is certainly a useful resource in cases in which the natural wines disagree.

On the whole, however, it must be admitted that there is no better beverage for gouty people than plain water, and they should be encouraged to drink largely of it, as an admirable aid to the elimination of nitrogenous waste.

PLAN OF DIET IN GOUT.

In view of the principles discussed above, the general directions for the diet in a case of chronic gout may be summed up as follows:

GENERAL RULES.

Meals should be as simple as possible.

Butcher's meat should only be eaten once a day, and in a very moderate amount.

Sugar and sweets should be taken sparingly.

Bread should be taken in the form of crisp toast or rusks.

Raw fruit should never be taken at a meat meal, and is best consumed early in the day.

If alcohol is necessary, it should be taken only in the form of brandy, whisky, or a light still Moselle.

ARTICLES TO BE AVOIDED.

1. Rich meat-soups: Oxtail, turtle, mock turtle, kidney, mulligatawny, hare giblet.
2. Salmon, mackerel, eels, lobster, crab, mussel, salted fish, preserved fish, smoked fish, tinned fish.
3. Duck, goose, pigeon, high game.
4. Meats cooked a second time. Hare, venison, pork, lean ham, sweetbreads, liver, kidney, salted corned or cured meats, pickled meats, preserved and potted meats, sausages; all articles of food pickled in vinegar; all highly seasoned dishes and rich sauces.

5. Tomatoes, beetroot, cucumber, asparagus, rhubarb, onions, mushrooms, truffles.
6. Peas, beans, lentils and oatmeal.
7. Rich pastry, rich sweets, new bread, cakes, nuts, dried fruits, ices, ice cream.

SCHEME OF DIET.

Half a pint of hot water (flavoured, if desired, with a slice of lemon peel) should be slowly sipped immediately on rising, and again just before retiring to bed.

Breakfast.

A selection may be made from the following articles: Whiting, sole or plaice, fat bacon, lightly cooked eggs, dry toast thinly buttered, tea infused for three minutes and then strained from the leaves.

Luncheon and Dinner.

Any clear soup.

White fish (except those forbidden above), chicken, pheasant, turkey or game (not high).

Butcher's meat (in accordance with the limitations already indicated).

One of the following vegetables: Spinach, Brussels sprouts, French beans, winter cabbage, savoy cabbage, turnip tops, turnips, celery, potatoes in moderate quantity (but not new potatoes).

Stewed fresh fruit.

Salads of green vegetables are permissible, but only with simple dressings.

Savouries are usually best avoided, but a morsel of cheese may be taken if free from mould.

RHEUMATOID ARTHRITIS, OSTEO-ARTHRITIS AND FIBROSITIS.

There is no necessity for any restrictions of diet in *rheumatoid arthritis*; on the contrary, an abundant and nourishing mixed diet is a most important part of the treatment, and the use of alcoholic beverages in moderation is permissible and sometimes advantageous. The old term 'rheumatic gout' has been responsible for much harm done to these patients, for it has often led to their being put on a restricted diet under the belief that their disease was in some way related to gout, and required the same sort of diet.

In *osteo-arthritis* no special dietetic treatment is called for unless, as is often the case, the patient is also corpulent. In such circumstances the diet should be directed to the treatment of the obesity on the lines already described.

The relation of diet to *fibrositis* is not clearly understood, but many believe that it is a condition associated with increased intestinal fermentation and decomposition. On the whole, the dietetic rules should follow those for gout, but individual peculiarities should always be taken into account.

GRAVEL.

The rational indications in the treatment of gravel would appear to be two in number: (1) To diminish the amount of uric acid which the urine contains; (2) to increase its solubility.

The former of these indications can be fulfilled, as far as the exogenous fraction of the urinary acid is concerned, by a diminution of the amount of uric acid yielders in the diet. We have already seen what are the best foods to select for that purpose. As regards diminishing that part of the uric acid which is formed in the body itself, we are just as much at a loss as in the case of gout. Some authorities pin their faith to a diminution of the protein-sparers—*i.e.*, carbohydrates and fat—in the food. It is possible that this may favour the conversion of uric acid into urea, though it must be admitted that such a view is as yet very far from being proved. At all events, this plan commended itself to such an experienced observer as Sir Henry Thompson.

He recommends¹ that the diet should consist of white fish, poultry, game, lean meat, unsweetened jellies, bread, cereals, pulses, green vegetables and apples, but no sweet fruits. A little butter may be taken, and milk in moderation. The things to avoid are cream, eggs, cheese, pastry, pork and other fat meats, the fatter kinds of fish, suet, much milk or butter, and all substances containing sugar. He advises that farinaceous foods should be mixed with light broths instead of milk, and flavoured with some condiment, such as a pinch of curry or a morsel of chutney, instead of sugar.

On the other hand, Goodhart,² after mentioning the case of a patient who suffered from gravel when on a milk diet, but got quit of it on changing to meat and port wine, says: 'I have come to be certain that in the majority of cases of uric acidity it is not a question of diet at all!'

The second indication mentioned above—that of increasing the solubility of uric acid in the urine—can be accomplished by rendering the urine less acid. As Sir William Roberts has said,³ the deposition of uric acid from an alkaline urine is a chemical impossibility. Now, we can certainly render the urine less acid by the free use of green vegetables and other foods containing alkaline salts of potash, but the same object can be accomplished so much more certainly and simply by the aid of drugs that the dietetic means at our disposal are hardly worth considering. The other factors concerned in keeping uric acid in solution are the presence of urea and mineral salts. An increase in these hinders the separation out of uric acid. For that reason it may be well that the diet should not be too poor in proteins, and that it should contain an abundance of common salt.

¹ 'Diseases of the Urinary Organs,' 8th edit., lecture xxv.

² An address on 'Acidity,' *Lancet*, 1900, i. 1.

³ Croonian Lectures, 1892.

As regards the question of beverages in gravel, the same remarks apply as in the case of gout.

OXALURIA.¹

In cases in which much oxalate of lime is separating out in the urine, one should select a diet which contains little oxalic acid and lime and plenty of magnesia, for the latter favours the solution of calcium oxalate. In order to meet the former indication, foods rich in oxalic acid should be avoided (*e.g.*, spinach, rhubarb, tea, etc. See table on p. 297), and also those which contain much calcium (*e.g.*, milk, egg, fresh vegetables. See p. 290), whilst the latter indication is met by the use of such foods as meat, cereals, bread, rice, peas, potatoes, apples, coffee, and beer.

DIETETIC TREATMENT OF SCURVY.

The essential in the dietetic treatment of scurvy is to supply the patient with a sufficiency of the antiscorbutic vitamin which is contained abundantly in fresh fruit and vegetables. The antiscorbutic power of fresh limes and lemons has been known since the seventeenth century, and these fruits still constitute the favourite remedy for the disease. It is important, however, that they should be fresh. Lime-juice which has been stored for a long time is apt to lose much of its value. An objection to lime-juice is its acrid taste, by reason of which it is sometimes found to be difficult to induce those who are exposed to the disease to take the juice regularly as a preventive. Lemonade made from fresh lemons is not open to this objection. Preserved vegetables, though of undoubted utility, appear to have a feebler antiscorbutic power than fresh. Sauer-kraut and tinned tomatoes are the most serviceable of preserved vegetables, and Captain Cook employed the former with success in some of his voyages. If fresh vegetables are unobtainable, germinated seeds may be used as a source of the vitamin.

Infusion of malt is another powerful antiscorbutic. Forster,² who accompanied Cook in his second voyage, describes a severe outbreak of scurvy and its cure by infusion of malt without any other change in the diet. He adds: 'The encomiums on the efficacy of malt cannot be exaggerated.' Some of the worst cases he saw took as much as

¹ See Klemperer and Tritschler, *Zeit. f. Klin. Med.*, 1902, xliv. 337.

² 'Notes from a Voyage Round the World,' by George Forster, vol. i., 1777

5 pints of the infusion per day. Here, again, it is important that the malt should be fresh, for its properties are impaired if it is allowed to become damp and mouldy.

Fresh meat juice is of undoubted value as a remedy for scurvy, and so, also, is milk.

Of beverages, French and Italian wines are admitted to possess antiscorbutic properties; but opinions regarding the value of cider in this respect vary considerably.

DIETETIC TREATMENT OF INFANTILE SCURVY.

The treatment of infantile scurvy is purely dietetic. The use of tinned foods and boiled or sterilized milk must at once be stopped, and the child put upon a due allowance of fresh milk. Fruit juice should be added to the diet, a few teaspoonfuls of grape or orange juice, sweetened, if necessary, with a little sugar, being given every day. Fresh raw-meat juice is also of value, and may be given in quantities of $\frac{1}{2}$ ounce daily. Baked potato, too, is of great service. It may be rubbed up with the milk into a thin cream and given through the bottle.

DIETETIC TREATMENT OF RICKETS.

Whether rickets be due to the want of a vitamin or not, there can be no doubt that one of the main factors in its production is an unsuitable diet. The diet may be either altogether deficient in nutritive properties or, more commonly, it is merely an ill-balanced one, in which the carbohydrate constituents are in relative excess when compared with the proteins and fats. The first step in treatment, therefore, is, in most cases, to decrease the starchy and sugary components of the food, and to increase the proteins and fats. With this object in view the use of all purely starchy foods—*e.g.*, sago, tapioca, and arrowroot, should be discontinued, and the same is true of patent and proprietary infant foods, most of which contain an excess of carbohydrates. On the other hand, the amount of pure cow's milk in the diet usually needs to be increased, and fats should be given liberally in the form of cream, bacon fat, butter, and cod-liver oil.¹ The use of condensed milk must be rigidly prohibited, as it is not only poor in fat, but, in most cases, contains a considerable excess of sugar. The nitrogenous constituents may be further supplemented by the use of raw beef-juice, scraped meat, or strong beef-tea.

Yolk of egg is also a valuable food for rickety children, containing,

¹ Vegetable fats are of much less value (see Vitamins).

as it does, not only protein and fat, but valuable organic compounds of phosphorus and iron, both of which elements the rickety patient needs. It may be given either in the raw state mixed with milk or very lightly boiled, and is usually well borne, even before the child is a year old.

Oat flour and whole wheat flour may be used in moderate quantities to thicken some of the milk, the former being, perhaps, specially useful in virtue of the fat, iron and phosphorus in which it is so rich.

3. Diet in Disorders of the Stomach.

GENERAL CONSIDERATIONS.

Seeing that the essential rôle of the stomach is a mechanical rather than a truly digestive one, the physical form of the food must always be of more importance in dyspepsia than its chemical composition. In proof of this, one finds that so long as the stomach is able to pass the food on into the intestine absorption and nutrition go on without impairment, even although the digestive juices of the stomach itself are no longer present.¹ The first rule to be observed, therefore, in drawing up a dietary for disorders of the stomach, is to see that the food is presented in such a form that the stomach has but little difficulty in driving it on into the duodenum. In practice this means that the food must be in a fine state of division, and should be carefully chewed.

The question of bulk must also be considered. The larger the mass of the food, the greater is the muscular labour imposed on the stomach. It is probably on this account that animal foods are, as a class, less troublesome to most dyspeptics than vegetable products. For the same reason, the meals in dyspepsia should be of small size, but taken at rather short intervals.

As regards the behaviour of the dyspeptic stomach to the different chemical ingredients of the food, great individual differences exist, and in no class of case is it more important to study the question of idiosyncrasy. In a majority of instances, however, one finds that fat is more apt to give offence than any other constituent. This is particularly true of *cooked* fat, probably because in process of cooking fatty acids, acrolein, and other irritating substances, are apt to be liberated. On the other hand, butter and bacon-fat can usually be managed with but little difficulty.

¹ See Von Noorden, 'Ueber den Stoffwechsel der Magen Kranken und Seine Ansprüche an die Therapie,' *Berliner Klinik*, 1893, Hft. 55, 1-19, and the same author, *Zeit. f. Klin. Med.*, 1890, xvii. 137; also Moritz, *Munch. Med. Woch.*, 1893, xl. 75.

We may now pass to the more detailed consideration of the dietetic treatment suitable in different forms of gastric disorder, leaving the discussion of some further general principles until we come to speak of 'functional' dyspepsias. In handling the subject it will be well to take up first those diseases of the stomach which are accompanied by definite organic change, and afterwards to consider the so-called 'functional' disorders in one group. Such an arrangement is admittedly unscientific, but it has the advantage of practical convenience, and our knowledge does not at present admit of any more satisfactory system of classification.

GASTRIC ULCER.

Ever since Cruveilhier clearly enunciated it, the principle has been accepted by all writers that rest for the organ is the point chiefly to be aimed at in arranging a diet for cases of gastric ulcer, and rest may be taken to mean the protection of the mucous membrane from both mechanical and chemical irritants.

In very severe cases, and especially if there has been recent bleeding, rest must be absolute. This is accomplished by cutting off all nourishment by the mouth, and feeding the patient exclusively per rectum. Many cases have been treated in this way for periods of even twenty days at a time,¹ but it is rarely necessary to continue the injections for more than three days. The details of such treatment will be considered in the last chapter.

After the period of rectal feeding, if all pain and vomiting have ceased, and in less severe cases from the outset, one can begin to feel one's way in giving food by the mouth. At first the diet must be strictly fluid, consisting of milk, diluted with lime or barley-water, or peptonized, given in quantities of about 5 ounces every hour, and at the body temperature. Small feeds of beef-tea may be given occasionally as a change.

After another week, if all is going well, one may advance to semi-fluid diet, the milk and beef-tea being thickened with a little corn-flour, arrowroot, fine oat flour, or biscuit powder. Some of the patent predigested cereal foods are useful at this stage, and lightly cooked eggs are also permissible. The Leube-Rosenthal Meat Solution is also well borne as a rule, or one may substitute for it well-made 'whole beef-tea,' or a little of one of the patent protein

¹ See 'Traitement de certaines Maladies de l'Estomac par la Cure de Repos absolu et prolongé avec Alimentation rectale exclusive,' Dr. A. P. Gros. Paris: Baillière et Fils, 1898.

foods (Plasmon, etc.) may be given stirred into clear broth or in combination with arrowroot. Peptonized milk gruel is also very helpful at this period.

After the lapse of another week one may add a little stale bread and butter, sweetbread or white fish, potato purée and custard, and gradually advance to underdone mutton, milk pudding, spinach and cauliflower, and from this to ordinary plain unirritating food (see Chronic Gastritis).

Any recrudescence of symptoms must be the signal for immediately retracing one's steps and reducing the diet, and even when convalescence is fairly established the patient must be careful for a long time to avoid all irritating and indigestible forms of food, and very hot or very cold articles.

The above may be described as the classical method of dieting cases of gastric ulcer, although some of the details have varied in the hands of different physicians. In modern times, however, Lenhartz has introduced a very different plan of diet which now goes by his name, and has been widely adopted. The guiding principles of the **Lenhartz diet** are these: (1) To promote healing of the ulcer by giving as much nourishing food as possible; (2) to 'fix' the acid of the gastric juice, and so prevent its interfering with healing by ensuring that the food contains a large proportion of protein; (3) to prevent distension of the stomach by the use of small feeds.

The method is carried out as follows:¹ The patient is kept absolutely in bed for four weeks, for the first two of which he is not allowed to move from the supine position for any reason whatever. All mental excitement must be avoided. An icebag is kept upon the stomach almost continually for the first two weeks. The dietary consists of eggs beaten up with sugar, or in some cases with wine, and iced; and of milk. These two foods are taken in small quantities at frequent intervals from a teaspoon, the quantity prescribed being spread over the day, and not given at definite meal-times. The first day 7 to 10 ounces of milk are given and one egg. The quantity is increased daily by $3\frac{1}{2}$ ounces of milk and one egg until $1\frac{3}{4}$ pints of milk and six eggs, or in some cases eight eggs, are reached. From about the third to the eighth day raw or almost raw mince is added, starting with an ounce in divided doses, either beaten up with the egg or alone; the next day, if the mince is well borne, 2 ounces are given; minced beef may be used.

¹ Spriggs, *Brit. Med. Journ.*, 1909, i. 825.

Food is given at first at hourly intervals from 7 a.m. to 9 p.m., but complete rest is allowed at night. Both the eggs and milk are iced and the eggs beaten up whole. Granulated sugar is added to the eggs on the third day. Some soluble casein preparation (Plasmon, Casumen, Sanatogen, etc.) may be used instead of the raw mince.

From the seventh to the eighth day boiled rice is added, followed by softened bread, and later by a small quantity of bread and butter. One or more eggs may now be lightly boiled. The diet is then gradually increased by the addition of mince or pounded fish, with a corresponding reduction of eggs, until by the end of the fourth week the patient is on an ordinary mixed diet containing the common foodstuffs, with the exception of indigestible solids, such as peas or other seeds. The patient is instructed to masticate very slowly. On the twenty-eighth day the patient is allowed to get up, and discharged from the sixth to the tenth week.

Lenhartz¹ claims that under this treatment (supplemented by the administration of iron and bismuth) pain disappears early, vomiting quickly subsides, and relapses are rare. The diet is also easier to carry out than the old 'starvation' plan, besides being more agreeable to the patient.

The dietetic treatment of *duodenal ulcer* should proceed on the same principles as that of gastric ulcer. Frequent feeds are here of special importance, owing to the rapidity with which the stomach empties itself.

ACUTE AND CHRONIC GASTRITIS.

The dietetic treatment of acute gastritis must proceed on the same lines as that of gastric ulcer. The affection, however, being usually of but short duration, rectal feeding is rarely required, all that is necessary being to withhold all food until vomiting has ceased, thirst being meanwhile relieved by sips of hot water or by sucking fragments of ice. If there is great depression, a little champagne may be given, preferably diluted with seltzer-water.

After the acute symptoms have subsided, the patient may gradually return to ordinary diet by the same stages as in gastric ulcer, but the steps of advance may usually be separated by periods of one or two days only, instead of by a week.

In the treatment of *chronic gastritis*, it is important to avoid the use of anything that may irritate the gastric mucous membrane or excite a secretion of mucus. Mustard, pepper, spices, and condiments of all sorts must be forbidden. Alcohol also should be avoided, especially in concentrated forms, for many of these cases

¹ *Med. Klin.*, No. 14, 1907. See also Langdon Brown (*Clin. Journ.*, 1908, xxxiii. 109).

are really brought on and maintained by the drinking of neat spirits. Coffee is apt to be injurious owing to the oily substances which it contains, but weak tea may usually be permitted.

Sugar is a very unsuitable food in these cases, more especially cane-sugar (see p. 277), for it excites a large secretion of mucus. Grape and milk sugar are much less likely to do harm. All cooked fats, pastry, sauces, and fat meats should be excluded from the dietary; but butter is usually well borne if taken in moderation, and some patients can even digest bacon.

Bread should only be taken thoroughly toasted, and potatoes in the form of purée. Cauliflower and spinach are the most suitable of vegetables. The food should be finely divided, eaten slowly, and but little taken at one meal. At the same time it is important to avoid mere 'slops.'

The following may be regarded as a typical diet schedule for an average case:

Breakfast.

Lightly-cooked eggs, white fish (boiled), a little crisp bacon (not too fat), fowl, game; dry toast with a little butter; a small cup of weak tea with milk but no sugar.

Luncheon.

Lean mutton, underdone, or underdone roast beef, white fish, etc., as at breakfast; mashed potato and a little spinach or cauliflower; dry toast; custard pudding or unsweetened jelly; a glass of alkaline mineral water, with perhaps a little claret or hock.

Tea.

A small cup of tea, as at breakfast; a slice of crisp toast and butter, or a plain biscuit or rusk.

Dinner.

A very little clear soup free from fat; white fish, without sauce; meat as at luncheon or breakfast, or a little sweetbread or tripe; vegetables as at lunch; custard, jelly, or fruit stewed without sugar, and free from skins or stones, or a little plain milk pudding; a lith or two of orange at dessert, the juice only being swallowed and no sugar taken; dry toast; a glass or two of good claret or burgundy and some mineral water; no coffee.

It may be well to point out that many cases of alcoholic gastritis stand midway, as regards the urgency of their symptoms, between the acute and chronic forms of the disease, and in such cases confinement to bed on a strict milk diet is often the most successful method of treatment.

DILATATION OF THE STOMACH.

1. *Obstructive.*

The kind of diet suitable for cases of dilated stomach must obviously depend upon the degree of pyloric obstruction. In all

cases, however, certain general principles must be observed: (1) It is important to avoid overburdening the weakened organ with any considerable mass of food at one time. The meals, therefore, should be small. (2) Substances must be excluded from the diet which are capable of supplying pabulum to the yeasts and sarcinæ so often found in the dilated viscus. The food should, therefore, be unfermentable. (3) Attention should be concentrated on rendering the food easily passed on into the intestine, rather than upon any attempt to make it capable of absorption in the stomach itself. The reason is that, even under the most favourable circumstances, the stomach absorbs but little, and when it is much dilated the process is probably arrested altogether.¹ Food should, therefore, be given either in a fluid or semi-fluid form or in a state of very fine division. (4) It must be remembered that water is not absorbed by the stomach, and if the pyloric stenosis is complete the tissues may suffer from water starvation. In such cases it is necessary to supply the blood with fluids by another route than the mouth. (5) In all cases of dilatation of the stomach, periodic lavage of the organ is a great aid to successful feeding.

In *complete pyloric obstruction* the patient must be fed per rectum (Chapter XXX.). An occasional saline enema, or the subcutaneous injection of salt solution, will be necessary to insure a due supply of fluids.

If the obstruction be *extreme, but not complete*, peptonized milk should be given in small and frequent feeds. The milk may be enriched by an unfermentable sugar, such as lactose, or by the addition of one of the concentrated protein foods (Plasmon, etc.).

In cases of *dilatation with comparative freedom from pyloric obstruction* the diet may follow very much the lines already laid down for chronic gastritis, but even greater care must be exercised in the use of farinaceous substances and fats, and the food should be finely divided. It is better to avoid all effervescing beverages, as they tend unduly to inflate the stomach. A little hot water may be drunk immediately after meals, and also with advantage on going to bed and on first rising in the morning.

2. Non-obstructive (Atonic Dilatation).

In cases of atonic dilatation the diet should be the same as for flatulent dyspepsia (*q.v.*). In extreme cases an exclusive protein diet is sometimes helpful (for details see p. 547).

¹ See Klemperer, *Deut. Med. Woch.*, 1889, xv. 170, and *Verhand. d. 8ten Con. f. Inn. Med.*, 1889, 271.

FUNCTIONAL DYSPEPSIAS.

Under this heading one may group for convenience that large and heterogeneous class of cases in which digestion is performed painfully or with difficulty, but in which no organic change in the organs of digestion can be discovered. In some of these cases the chemistry of the stomach is at fault, but in many the basis of the condition would seem to consist rather in a hyperæsthesia of the stomach, an undue sensitiveness to normal irritants.

In treating them it is essential to keep one or two principles clearly before one's mind. (1) In many of these cases the patient's general nutrition requires to be considered rather than his mere gastric sensations. If the nervous system and blood can be raised to a proper level of health, the dyspeptic symptoms often disappear spontaneously. For this reason great harm may be done by too strict dieting. The tendency in such patients is to go on cutting off one article of food after another until a state of semi-starvation is induced, in which it is impossible for any organ in the body properly to perform its work. Instead of adopting this plan, it would be well if such patients could be induced to follow the advice of King-Chambers, and add to the diet any article of food that had once been found to agree, rather than to cut out of it anything that had ever disagreed. (2) Mental and physical rest, preferably in bed, is a great and sometimes indispensable aid to treatment. It acts both by economizing vascular and nervous energy and by enabling nutrition to be efficiently carried out upon a minimum quantity of food, and therefore with the least amount of labour on the part of the digestive organs. (3) In no class of gastric disorders does the question of idiosyncrasy play a greater part than in this. Due regard must therefore always be paid to the inclinations of individual patients in arranging the diet-sheet.

In all cases of this class the same elementary dietetic rules must be observed as in other forms of digestive trouble. The food must be in a suitable physical form, all notoriously indigestible articles being avoided; the meals should be properly arranged, and chewing carefully performed. To these simple directions one need only add that good cooking and attractive presentation of the meals are here of the first importance.

In all cases the most easily digested foods should be selected, these being :

- (a) Meats: Mutton, venison, sweetbreads, chicken, tripe, rabbit, grouse, partridge, pheasant.
 - (b) Fish: Whiting, sole, turbot.
 - (c) Farinaceous foods: Stale white bread, rusks, plain biscuits, rice, tapioca, sago, arrowroot.
 - (d) Vegetables: Asparagus, sea-kale, spinach, cauliflower, French beans.
 - (e) Fruits: Baked apples, or the juice of oranges or grapes.
- 'Made dishes,' twice-cooked meats, sauces, pastry, pickles, cheese, sweets and preserves should be avoided altogether. Meat should be underdone; fish should be boiled or steamed.

The special rules of diet will depend upon the particular form of dyspepsia with which one has to deal. For practical purposes one may distinguish the following varieties:

1. Defective secretion (hypochlorhydria and achylia).
2. Excessive secretion (hyperchlorhydria).
3. Defective motility ('atonic' dyspepsia).
4. Excessive sensibility (gastralgia).

The principles to be observed in prescribing rules of diet in each of these forms may now be briefly discussed.

1. *Defective Secretion*.—In cases of this sort the mechanical form of the food is of much greater importance than its chemical composition. So long as the motor power of the stomach is unimpaired the defect of secretion is not of much account, for digestion will be fully performed in the intestine. The food should therefore be finely divided (pounded, minced, or sieved), in order to facilitate its passage through the stomach, and thorough mastication insisted upon. If this principle be observed an ordinary mixed diet may be safely prescribed. Even when secretion is completely arrested (achylia) this may be done without risk, unless there is evidence of protein decomposition in the intestine, as shown by offensive eructations or a tendency to diarrhoea. In that case meat should be strictly limited in amount, or even abolished from the diet altogether, its place being taken by peptonized milk and the casein preparations (e.g., Plasmon).

2. *Excessive Secretion*.—Much discussion has taken place as to whether the diet, in cases of hypersecretion, should be mainly animal or vegetable in constitution.¹ On the one hand, there is no doubt that an animal diet 'fixes' the excess of hydrochloric acid most efficiently, whilst on the other there is abundant evidence to show that in the long-run a mainly vegetable diet leads to a permanent diminution of acid formation. An animal diet is therefore the best palliative, whilst a vegetable diet is more strictly curative in effect. The writer's own experience is that in practice

¹ See Schloss, 'Vegetabilische oder Fleischnahrung bei Hyperacidität' (*Arch. f. Verdauungs Krankh.*, 1907, xiii, 233).

a predominatingly animal diet gives the best results, whilst other means may be relied upon for actually lessening secretion (*e.g.*, the free use of fats, administration of bismuth, etc.).

On the other hand, it is reasonable to exclude all direct stimulants of secretion. Under this heading come such substances as common salt, extractives of meat, the various condiments, and alcoholic beverages.

As there is both experimental and clinical evidence¹ to show that fats have a restraining influence on gastric secretion they should be partaken of freely. As much as an ounce of almond oil may be given before meals with advantage, especially in cases complicated by ulceration.

Foods rich in carbohydrates, on the other hand, must be eaten sparingly, as free acid appears in the stomach very early after their use, and the conversion of their starch by the saliva is interfered with. For this reason the addition of malt to farinaceous foods is often of great service in cases of hyperacidity. Cane-sugar being a potent excitant of secretion should be avoided altogether. It is particularly harmful in cases of acid gastritis. It stands to reason that where 'acidity' of the stomach is complained of, all sour articles should be banished from the diet. Vinegar and some wines are examples in point.

The application of the above principles may be expressed in the following rules :

DIRECTIONS FOR DIET IN HYPERCHLORHYDRIA.

1. The diet should consist mainly of animal constituents (milk, eggs, fish, and meat).
2. Salt, pepper, mustard, meat extracts, gravies, meat soups, spices, pickles and condiments should be altogether avoided.
3. Bread and potatoes should be taken very sparingly, but bacon and butter may be eaten freely.
4. Sugar and all sweet or sour things should not be eaten.
5. Alcoholic beverages should be avoided. The best drink at meals is an alkaline water such as Apollinaris.

3. *Defective Motility* (Atonic or Flatulent Dyspepsia).—In this form of dyspepsia the mechanical form of the food, as in cases of defective secretion, is of chief importance. It is essential to avoid burdening the stomach with large quantities of material, especially such as is of a bulky sort (*e.g.*, green vegetables). The simultaneous presence in the stomach of solids and liquids is specially injurious, for in such circumstances the fluid part of the meal is retained for a long time in the organ, and tends to dilate it by its mere weight. The meals

¹ See Backman (*Zeit. f. Klin. Med.*, 1900, xl. 224), and Craven Moore and Ferguson (*Proc. Roy. Soc. of Med., Laryng. Sect.*, 1909, iii. 25).

should therefore be dry, and care should be taken not to drink for at least two hours after solid food has been taken.

If flatulence be much complained of—as it often is—green vegetables and the pulses should be avoided altogether, on account of their ‘windy’ tendency, and the starchy foods should be strictly limited. The necessity for reducing the starches in flatulence is a principle derived from experience for which it is difficult to find a satisfactory reason. It certainly does not reside in the ‘fermentable’ character of starchy food, for the flatulence of atonic dyspepsia is almost certainly not due to fermentation, but there is no doubt about the practical harmfulness of the carbohydrates, explain it how one may.

Restriction of fluids is also of special importance in cases of flatulence, tea, especially, being peculiarly noxious to these patients. On the other hand, it is in atonic dyspepsia that the moderate use of alcoholic beverages at meals, preferably in the form of a little sound wine, often gives the happiest results, for alcohol is a stimulant both to the secretory and motor functions of the debilitated stomach.

The above general principles may be summed up in the following directions :

DIRECTIONS FOR DIET IN ATONIC AND FLATULENT DYSPEPSIA.

1. The following articles should be avoided :
Green vegetables (except spinach and cauliflower tops); turnip and carrots; peas, beans, and lentils; fruits (except the *pulp* of baked apples or stewed prunes); sugar and jam; soups.
2. Potatoes should be taken very sparingly.
3. Crisp toast, rusks or pulled bread should be taken in place of ordinary bread.
4. *As little fluid as possible should be taken at meals.* A little hot water may be sipped between meals if flatulence is troublesome.
5. Tea should be avoided entirely, and coffee only taken with plenty of milk.

The above rules are applicable in all cases of atonic dyspepsia of moderate degree. In severe cases, however, in which there is pronounced dilatation of the stomach (non-obstructive), an ‘*exclusive protein diet*’ is sometimes indicated. Such a diet is described in detail elsewhere (p. 547). Far more commonly one has to deal with cases in which the gastric atony is merely part of a general condition of neurasthenia, and it is then often complicated (especially in women) by visceral ptosis. In such cases one must ignore the gastric symptoms and improve the general state of nutrition at all costs, for it is only when this has been accomplished that normal digestive power returns. The best way of doing this is by a course

of *over-feeding* combined with rest in bed and massage (Weir Mitchell treatment or rest-cure). For details of such treatment see p. 503.

4. *Hyper-sensibility of the Stomach* (Gastralgia).—The diet here must be of a 'bland' character, such as is suitable in the early stages of gastric ulcer (see p. 516). Rest in bed greatly facilitates the use of such a plan. So soon as pain disappears a liberal mixed diet should be adopted in order to improve the state of the blood and the general nutrition of the patient. Red meat should be given as early as possible, particularly as patients who suffer from gastralgia are often anæmic and debilitated from the habitual use of a poor diet defective in protein. If these principles be observed no special rules will be required.

DISEASES OF THE INTESTINES.

In *acute diarrhœa* the chief point to be aimed at in feeding is to select a diet which shall be unirritating, and shall leave as small an unabsorbed residue as possible. If the diarrhœa be very severe, it may be necessary to withhold all food for a day or two, nothing being given by the mouth but a little barley-water to quench thirst. When the symptoms have somewhat abated, and in milder cases from the outset, one can allow weak decoctions of cereal preparations, such as arrowroot, rice, cornflour, sago, or one of the patent cereal foods. These should be given at the body temperature.

By-and-by one can begin to give milk, but tentatively and always safeguarded with a little lime-water. Raw-meat juice, alum-whey, egg-white solution, and the pulp of underdone beef are also useful; but all solutions containing the extractives of meat are best avoided.

If the patient be very thirsty, he may be allowed sips of cold tea or diluted red wine, or water flavoured with a little lemon-juice.

In cases of *chronic diarrhœa*, all bulky foods and those which leave a large residue or which contain laxative principles should be avoided. Amongst such are green vegetables, fruits, and all sour things. Hot liquids should not be taken. Alcoholic beverages are best avoided. Milk must be given with caution: in some cases it increases the diarrhœa, in others not. It is safest when freely diluted with lime-water.

The further details of the diet must depend upon the cause of the diarrhœa. If, for example, it be due to defective secretion of gastric juice ('*gastrogenic*' diarrhœa), the diet must be arranged as in cases of achylia (p. 522). If it be due to *fermentation* in the bowel, the diet must be arranged according to the nature of the fermentation. If it be the carbohydrates which are at fault, as shown by the passage of

acid stools, the starches must be reduced to a minimum. In such a case a diet of milk, casein preparations, and underdone meat may suit best. If, on the other hand, there is decomposition of proteins with alkaline offensive stools, meat must be withheld entirely, and the diet consist of milk and carbohydrates. If the stools are white, greasy, and show fat droplets, fat should be withdrawn from the diet, and skim milk, casein preparations, carbohydrates, and underdone meat made the basis of the regimen.

In cases of **nervous diarrhœa** there are no special rules of diet, but the experience of the patient should be made the guide as to what to eat, drink, and avoid.

In the treatment of the special form of diarrhœa known as **sprue**, a strict milk diet is generally recommended by the best authorities. At first 3 pints of milk are allowed daily, in hourly or two-hourly feeds. In a few days the quantity may be increased to 5 pints a day, and after ten days to as much as 6 or 7 pints in the twenty-four hours. The strict milk diet should be continued for six weeks after the stools have become solid, after which the diet may be gradually advanced, much in the same way as in gastric ulcer. If after a period of rigid milk diet the patient is unable to return to ordinary food, a course of 'Salisbury treatment' (p. 547) may be useful. Strawberries have been asserted to have an almost specific influence in controlling the diarrhœa of sprue, and as much as 1½ pounds of them have been given daily with apparent success.¹

Authorities are divided as to the best form of diet in cases of **dysentery**. In acute cases mild starvation is probably the best plan, beginning with thin broths and decoctions of cereals as in acute diarrhœa, and passing on to milk, either plain, peptonized, or suitably diluted, so soon as the tongue is clean. In chronic cases a more generous diet is advisable, but all coarse and irritating foods and such as leave a large residue in the bowel should be avoided. Bilberries are strongly recommended by Dernstein² in chronic dysentery.

In **acute and ulcerative colitis** the diet should be the same as for acute and chronic dysentery respectively. In **muco-membranous colitis** two distinct plans are advocated: (1) Most French writers, influenced by their experience at Plombières, recommend a diet which leaves as little residue in the bowel as possible, the diet consisting of lightly cooked eggs, pounded meat or fish, sieved potatoes, toast, rusks or biscuits, rice, the Italian pastes, milk, if it can be digested, and the pulp of ripe fruits. (2) Von Noorden, on

¹ For an illustrative case, see a paper by Young, *Lancet*, March 28, 1903

² *Brit. Med. Journ.*, February 7, 1902.

the other hand, recognizing that constipation is an essential part of the disease, urges that the diet should be bulky, and contain much cellulose and other articles suitable for cases in which there is sluggish action of the bowels.

The irritating effects of such a diet are obviated by adding to it large quantities of fat in various forms. Ransome¹ gives the following as a typical dietary which possesses the essentials of the treatment, but in which modifications, especially in quantities, must be made to suit individual cases :

- 7 a.m.— $\frac{1}{2}$ pint milk-cream mixture.
- 8 a.m.— $\frac{1}{2}$ pint Kissingen water.
- 9 a.m.— $\frac{1}{2}$ pint cocoa with cream (2 oz.), bread (2 oz.), butter, marmalade.
- 10.30 a.m.—Massage.
- 11.30 a.m.—12 oz. special soup; 3 oz. bread; 1 oz. butter; potatoes, green vegetables, baked apple, stewed pears, or boiled gooseberries; cream. Rest for two hours with hot bottle on abdomen.
- 4 p.m.— $\frac{1}{2}$ pint milk-cream mixture.
- 7 p.m.—Dinner like lunch, but with 3 oz. bread and 2 oz. butter.
- 9.30 p.m.— $\frac{1}{2}$ pint milk-cream mixture.

A description of certain items in this dietary may be found useful.

Milk-Cream Mixture.—This consists of equal parts of milk and cream, and one teaspoonful of sugar of milk. The cream should contain 30 per cent. of butter-fat, and nearly a pint should be taken in the twenty-four hours.

Kissingen Water.—This is used as a stomachic, not as an aperient.

Bread.—This must be of the coarsest flour obtainable. The larger proportion of husk it contains the better. The usual brown bread sold as whole-meal bread is not sufficiently coarse.

Butter.—The average total quantity should be $\frac{1}{2}$ lb. a day; 5 or 6 oz. of this is taken with bread, the remainder being used with the vegetables.

Special Vegetable Soup.—This should be prepared carefully according to the following directions. Preparation of vegetable pulp: Place a breakfast-cupful of lentils or dry peas in a pan in sufficient cold water to cover them, and allow them to soak all night. In the morning add a slice of fat bacon about 6 ins. by 2 ins. and $\frac{1}{4}$ in. thick, and boil for one hour. Put one teaspoonful of butter and one of flour into a small pan on the fire, add a teacupful of milk gradually, stirring all the time until well mixed. Then add a teaspoonful of cream and mix with the pulp. To vary the flavour, a sufficient quantity of green peas, spinach, asparagus, or other green vegetable should be placed in cold water and boiled for half an hour, rubbed through a sieve, and added to the soup. The soup should contain all the husks of the peas or lentils, and should be more of the consistency of porridge than of soup.

Meat.—This may be of any kind, but is more easily digested if prepared as follows: It is cut up finely with a sharp knife, and thoroughly pounded in a mortar while raw. It is then mixed with sufficient beaten-up white of egg and milk to make a thick cream, placed in a china cup, and boiled in a pan of water for three to five minutes, being well stirred during the process.

Vegetables.—These should be of the coarse green varieties—cabbage, spinach, Brussels sprouts—well boiled and mashed with butter.

¹ See Abst. in *Ther. Gaz.*, November 15, 1908.

As the diet is rather trying at first, it is best to begin treatment with the patient in bed, preferably in a hospital or nursing home. When a natural daily evacuation of the bowels has been established, the patient is allowed to get up, and may gradually return to ordinary life and to a more usual diet, but plenty of coarse bread, vegetables and fat should remain a permanent feature of the regimen.

In the acute **diarrhoea of infancy** all milk must be stopped for at least twenty-four hours, and nothing given but egg-white solution (the white of one egg to $\frac{1}{2}$ pint of water, flavoured with a little milk-sugar). Raw-meat juice and alum-whey are also very useful in such a case, and at a later stage the white of egg mixture may be made with whey instead of with water. When milk is begun again, it should be given peptonized at first, and well diluted with lime-water. The administration of salt solution, either per rectum or subcutaneously, will often tide over the crisis in an acute case.

In the treatment of **constipation** much can be accomplished by suitable diet. Food can increase peristalsis either by (1) mechanical or (2) chemical action.

Foods which leave a large amount of residue or 'ballast' in the intestine act in the former way. Generally speaking, all foods rich in cellulose belong to this class, *e.g.*, oatmeal, green vegetables, wholemeal bread, and some fruits. All of these should therefore find a place in the diet. Water also acts in a large measure mechanically by increasing the fluidity of the intestinal secretion, but in part also its action may be reflex. It is best given cold the first thing in the morning. In districts in which the water contains much lime a pure artificial aerated water should be taken instead (*e.g.*, Salutaris). Fats and oils, too, act as mechanical lubricants, and sufferers from constipation should partake of all of them freely, especially if the motions are small and dry. Honey, treacle, and marmalade have also a slightly aperient action.

The chemical action of foods is usually brought about by the organic acid which they contain. It is probable, indeed, that foods rich in cellulose owe their laxative properties largely to the fact that they are very apt to undergo fermentation in the intestine, with the production of lactic, acetic, and other acids.

Fruits are, of course, the foods richest in organic acids, and should always be freely used in such cases. They may be taken either fresh or stewed, figs and prunes being perhaps the best forms to select.

Of beverages, cider has a decidedly laxative action, though it is apt to produce colic in many persons, and malt liquors sometimes act similarly. On the other hand, red wines are usually astringent,

and so often is sherry. Milk is also a very constipating fluid, and so are tea and coffee to some persons. At least 3 pints of liquid should be taken in the course of the day.

These principles are expressed in the following rules for patients :

DIRECTIONS FOR DIET IN CHRONIC CONSTIPATION.

1. The following foods should be partaken of freely :
 Porridge made from medium oatmeal ; whole-meal bread ; gingerbread and 'ginger snaps' ; green vegetables ; fruits (fresh or stewed—especially stewed prunes or figs and baked apples) ; marmalade, honey and treacle.
 Fats—*e.g.*, bacon fat, butter, salad oil.
2. The following should be avoided :
 Milk ; eggs ; strong tea and coffee ; red wines.
3. A glass of cold water should be taken on rising, and a few French plums may be eaten before going to bed.

DISEASES OF THE LIVER.

In the dietetic treatment of **hepatic cirrhosis** the first indication is to counteract the tendency to gastric catarrh, which almost always co-exists along with the derangement of the liver even if it be not causally related to the latter. The most suitable diet, therefore, will be one which follows very much upon the lines of that already laid down for cases of chronic gastritis. Seeing that the liver cells also serve as storehouses for fat and glycogen, it will be well also that all rich, fatty foods should be avoided, and that carbohydrates, particularly sugar, should be eaten very sparingly. Alcoholic beverages should be strictly forbidden, except, perhaps, in the very latest stages of the disease, and all spices and condiments must also be looked upon as harmful.

There are but few indications to be met in the dietetic treatment of cases of **gall-stones**. Seeing that the taking of food into the stomach stimulates the expulsion of bile, it will be well to see that the meals are rather frequent—at least five being taken in the course of the day. There is no scientific justification for qualitative alterations of the diet, however, for it does not seem that the ingestion of food containing much cholesterol or salts of lime appreciably influences the composition of the bile,¹ even though it might seem on *a priori* grounds that such articles would be likely to promote the formation of calculi. On the other hand, most clinical observers are agreed that the drinking of large quantities of water is advisable,

¹ See Aldor, *Zeit. f. Physik. und Diät. Therapie*, 1903, vii. 201. Notwithstanding this, it is advisable to limit the consumption of eggs and milk by patients who suffer from gall-stones, as these are both foods rich in cholesterol.

even although there is no actual experimental evidence to show that the fluidity of the bile is increased thereby.

In cases in which jaundice is a prominent symptom the consumption of fats should be greatly restricted, for if bile is not entering the intestine freely, the absorption of fat is interfered with, the result being that it not only retards the digestion of the other constituents of the food, but itself undergoes bacterial decomposition, with the production of irritating fatty acids. The diet should be of a simple character, and may, with advantage, contain plenty of fresh vegetables and fruit. Milk, on the other hand, should be avoided or only given skimmed, or whey may be substituted for it.

In cases of 'biliousness'—a condition which is perhaps due to functional disorder of the liver—milk, eggs, and all rich and greasy foods should be avoided, and meat taken sparingly. The diet may consist of the white meats, and fish, toast, vegetables, and fresh and stewed fruits. Alcohol should be forbidden entirely. In chronic cases the diet should be the same as for chronic gastritis (*q.v.*).

4. Disorders of the Circulation.

The consideration of the dietetic treatment of cardiac disease follows naturally upon that of digestive disorders, for no two organs are in closer sympathy than the heart and the stomach, and by lightening the work of the latter one indirectly aids the former. When the heart's action is impaired, the diet should be easily digested and non-flatulent, and the food should be given in small quantities at a time at not too short intervals, and should be rather dry. The limitation of fats is also quite as important as in cases of dyspepsia, for there is reason to believe that fats are badly absorbed in cases of severe cardiac disease.¹ Carbohydrates must also be used very sparingly, owing to their tendency to produce flatulence. Hence it is that the diet of cardiac disease must be pre-eminently nitrogenous in its nature. The object of all this is to prevent overdistension of the stomach, which is apt to be followed by embarrassment of the heart. In the main, therefore, the same principles must be attended to as in the dietetic treatment of dyspepsia.²

¹ See Grassmann, *Zeit. f. Klin. Med.*, 1889, xv. 183.

² G. W. Balfour ('The Senile Heart,' p. 240) lays down the following dietetic rules for patients with weak hearts:

- i. There must never be less than five hours between each meal.
- ii. No solid food is ever to be taken between meals.
- iii. All those with weak hearts should have their principal meal in the middle of the day.
- iv. All those with weak hearts should have their meals as dry as possible.

The value of a **dry diet** in cardiac disease has been specially insisted upon by several writers.¹ Its beneficial action is probably exercised in several ways: (1) In cardiac disease fluids are absorbed very slowly, and are therefore apt to interfere with digestion and produce flatulence; (2) if fluids are withheld, the blood tends to become more concentrated, and water then passes into it out of the tissues, and thus the absorption of dropsical effusions is aided;² (3) the sudden entrance of any considerable quantity of fluid into the circulation throws a mechanical strain upon the heart by increasing the amount of blood which has to be propelled round the circulation. Thus limitation of fluids lessens the work of the heart (see also p. 301).

In cardiac dropsy, therefore, and especially if complicated by obesity, the quantity of fluid allowed should be limited to about 20 ounces per day, and not more than 5 ounces should ever be taken at one time. If much thirst is experienced, it may be relieved by sucking a few acid drops.

The following is a scheme of diet for patients with weak hearts:

Breakfast, 8.30.

About 1½ oz. of dry toast with butter, a lightly-cooked egg or a little white fish; 3 to 5 oz. of tea or coffee with cream and sugar.

Lunch or Dinner, 1.30 to 2 o'clock (the principal meal of the day).

Two courses only, fish and meat, fish and pudding, or meat and pudding. *Soups, pastry, pickles and cheese absolutely forbidden.* The most digestible forms of meat or fish to be selected; one potato or a little spinach. Any form of simple milk pudding may be taken or a little fruit. During the meal 4 to 5 oz. of hot water may be sipped if desired.

Tea, 5 to 6 o'clock.

3 or 4 oz. of weak tea with cream and sugar, but *no solid food.*

Supper, about 7 o'clock.

Must always be a light meal. May consist of white fish and a potato, or toast with butter, or some milk pudding or bread and milk. 4 or 5 oz. of hot water may be taken at bedtime.

In the treatment of the **flatulence**, which is often such a distressing accompaniment of heart failure, especially when associated with emphysema, the meals should also be small and dry. Biscuits or rusks should be substituted for bread, and lemon-juice for vegetables.

¹ See Oertel, Leyden's 'Handbuch der Ernährungstherapie,' Bd. ii., p. 55 *et seq.*; also Cheadle, *Lancet*, 1877, ii. 758, 794, 838, 877; Dickinson, Clifford Allbutt's 'System of Medicine,' v. 690; and Balfour, 'The Senile Heart,' chap. x.

² Cheadle particularly insists upon the importance of limiting the intake of fluids in cases of ascites, even when due to cirrhosis (*Lancet*, 1900, i. 903).

Meat should be only once cooked, and rather underdone, and all soups, sauces and fruits should be avoided.

While some such diet as the above may be adopted with advantage by patients with weakness of the muscular substance of the heart, it must be remembered that in cases of acute cardiac disease, and often enough where there is severe impairment of compensation, and consequently great interference with digestion, it may be necessary to have recourse to fluid diet, milk or peptonized milk being given in small quantities at short intervals of time.

The dietetic treatment of aneurysm requires a word of mention. Our object here must be to diminish the force of the heart and to increase the coagulability of the blood.

Valsalva claimed that he was able to do this by a process of starvation. He used only bread and water or pudding and water, giving as little as half a pound of pudding night and morning. His patients often became so weak that they were unable to sit up in bed. Some good observers have spoken highly of this method,¹ but for the most part it is now but rarely adopted.

Tuffnell's diet for aneurysm is somewhat less severe, and can be followed out for longer periods. He allowed 4 ounces of bread-and-butter, 2 or 3 ounces of meat, 4 ounces of milk, and 3 or 4 ounces of claret, daily. Here again the chief characteristic of the diet is its extreme dryness.

In cases of high arterial tension secondary to chronic nephritis, the diet must be the same as in that disease (p. 536). In primary cases of high tension, diet is often of little use in treatment, but it may be necessary in gross feeders to reduce the total intake of food and especially of meat and things derived from it—*e.g.*, soups. Salt should also be forbidden. Alcohol is probably best avoided, and in the main the diet may follow much the same lines as in renal cases. It will often be found, however, I think, that sufferers from primary high tension have always been abstemious people, and for such, of course, dietetic rules are of no use.

¹ See King Chambers, 'Lectures, chiefly Clinical,' lecture xxiv.

5. Respiratory Diseases.

1. **Pneumonia.**—The diet in pneumonia should proceed on the same principles as in any other acute fever (p. 480); but as the disease is usually one of short duration, and as the digestive functions are apt to be considerably impaired, particular care should be taken not to overload the stomach. From two to three pints of milk, plain, diluted, or citrated, with half a pint of broth should be sufficient in the twenty-four hours. Weak tea may be allowed, and plenty of water or barley water. The indications for the use of alcohol are the same as in any other acute fever.

2. **Bronchitis.**—In acute bronchitis a diet of 'hot slops' (hot milk, broths, gruels, tea, etc.) is best, as it tends to promote secretion from the tubes. In chronic bronchitis the diet should be much on the lines of that in cases of cardiac disease (p. 531), but in ill-nourished patients plenty of digestible fats should be given.

3. **Asthma.**—In asthma the diet should be a spare, dry one, following very much the scheme given for heart cases (p. 531). The last meal should always be a small one. In well-nourished subjects it is often advisable to have a fast day once a week, or at longer intervals, during which nothing but water, tea, and perhaps a little broth or diluted milk is taken.

In some asthmatic patients there is an idiosyncrasy to certain food proteins—*e.g.*, those of eggs, fish, etc., and if this is known to exist, or is demonstrated by the skin test, the offending article should of course be avoided.

4. **Pulmonary Tuberculosis.**—The diet in this condition should follow the principles applicable in all cases of tuberculosis (p. 505), but may require modification in accordance with the digestive capacity of the individual case.

6. Renal Disease.

In the dietetic treatment of renal disease the principles chiefly to be borne in mind are: (1) To diminish the amount of work thrown upon the kidneys; (2) to avoid all ingredients in the food which, during their excretion, are calculated to irritate the diseased organs.

1. As the kidneys are the chief route for the excretion of the products of nitrogenous waste, the former of these principles involves

that the diet should be not too rich in proteins,¹ and should, as far as possible, be free from nitrogenous extractive matters.

We shall see immediately, however, that as regards chronic renal disease, at any rate, the former of these indications must sometimes be overridden by more pressing considerations. The amount of salt in the food should also be diminished as far as possible, for the burden of excreting it falls entirely upon the kidneys.

2. Amongst the substances calculated to irritate the kidney in the process of their excretion are such articles as spices, mustard, pepper, curry, ginger, radishes, and perhaps asparagus. Alcohol, especially in concentrated forms, is also strongly contra-indicated in most cases of renal disease for the same reason, and of non-alcoholic beverages ginger ale should be avoided, owing to the fact that it contains either ginger or capsicum or both.

In acute renal disease an exclusively milk diet is, by common consent, the best method of treatment. That this is not a mere general impression is proved by the fact that in such cases a milk diet is found to increase the elimination of urea and other solids, and to decrease the amount of albumin in the urine.² It must be remembered, however, that milk is a bulky food, and by introducing much fluid into the circulation it increases vascular tension, throws a strain upon the heart, and aggravates the tendency to dropsy. The quantity allowed should therefore be restricted to three pints a day, and the nutritive value of the diet raised by the addition of cream or other fatty food, or by allowing moderate quantities of one of the more starchy cereals, such as rice.

The milk may be given either plain or, what is better, diluted with some alkaline mineral water, and if the patient tires of it kephir, or butter-milk may be used as a partial substitute.

The beneficial effects of milk cannot be altogether due to the fact that it is poor in proteins. As a matter of fact, relative to its other constituents, milk contains a very considerable proportion of nitrogen. It is not improbable that its advantages are to be partly attributed to the chemical peculiarities of casein, and to the fact that on a milk diet intestinal putrefaction is reduced to a minimum. The addition to the milk diet of substances containing only carbohydrates and fats,

¹ The belief that a liberal supply of protein is required in renal disease in order to make good the albumin excreted in the urine is baseless. Assuming an average excretion of $\frac{1}{2}$ per cent. albumin, the daily loss would not amount to more than 8 grammes, and would be covered by the protein contained in the whites of two eggs. Wordley (*Quart. Journ. of Med.*, 1920, 14, p. 88) found that variations in the amount of protein in the diet have no effect on the amount of protein excreted in the urine.

² See Ralfe, *Trans. of the Med. Soc.*, 1894, xvii, 251.

as above recommended, is open to no theoretical objection, and might perhaps be more extensively adopted in practice.

In subacute nephritis the prolonged nature of the complaint necessitates a more solid diet. The principle of keeping the proportion of protein as low as possible (certainly not more than 80 grammes daily) must still, however, be maintained. The more nearly the case stands to the acute form the more extensively should milk be used as the chief source of protein, but in the more chronic forms of the disease other animal foods may be allowed in small quantity. It is the custom to select from these the **white meats**, such as fish, chicken and veal, as preferable to the dark meats. This preference is based upon the belief that the former contain less nitrogenous extractive matter than the latter. That this is true as a chemical fact has been denied by Von Noorden and others,¹ and recently the matter has been put to a practical test by Pabst.²

He compared the amount of albumin in the urine of patients with subacute nephritis (large pale kidney) on (1) milk diet, (2) a diet containing $\frac{1}{2}$ pound of chicken or veal, (3) a diet containing a similar quantity of ordinary meat, with the following results:

AVERAGE DAILY EXCRETION OF ALBUMIN.

Diet.	First Case.		Second Case.
	First Experiment.	Second Experiment.	
Milk	14.5	15.1	12.9
White meat	13.0	12.7	12.1
Milk	12.7	11.4	13.4
Ordinary meat	12.9	12.4	13.1
Milk	12.0	10.9	12.4
Mixed diet	13.0	8.9	12.2

He concludes that the kind of diet had no appreciable or constant influence upon the composition of the urine or the amount of albumin which it contained. Other observers have obtained similar results.³

It must be remembered, however, that the white meats, and

¹ See *Verhand d. 17ten Cong. f. Inn. Med.*, 1899, 386, and Offer and Rosenquist, *Berlin. Klin. Woch.*, 1899, xxxvi. 937, 968.

² *Berlin. Klin. Woch.*, 1900, xxxvii. 547. For earlier experiments of a similar kind, see a paper by Hale White ('On the Influence of Various Diets upon the Composition of the Urine and the General Condition of Patients suffering from Chronic Bright's Disease') in the *Med. Chir. Transactions*, 1894, lxxvi. 279.

³ See Kaufmann and Mohr 'Beiträge zur Diätetik der Nierenkrankheiten, *Zeit. f. Klin. Med.*, 1902, xlv. 441.

especially fish, are, weight for weight, poorer in protein than the others, and therefore if one wishes to keep the amount of nitrogenous matter in the diet low there may still be advantage in having recourse to them, although it must be admitted that the recent observations just quoted tend to show that the dark meats may not be so harmful as was supposed, provided they are used in moderation.¹ It is probable, too, that the same diet may not suit all patients equally well. Sparks and Mitchell Bruce,² in a case very similar to those of Pabst, certainly found that milk gave better results than anything else. One may therefore require to feel one's way in selecting the most suitable diet.

The non-nitrogenous constituents of the diet in subacute nephritis call for less consideration. Fats and carbohydrates in the form of cream, cereals, vegetables, and fruits, may be freely allowed, but alcohol and all irritating substances should, as in all renal cases, be avoided.

In arranging the diet for cases of **chronic nephritis**, regard must not be paid too exclusively to the requirements of the kidney. Important as it is to reduce the nitrogenous waste matters in the urine as much as possible, this must not be done at the expense of other organs. The maintenance of a due degree of cardiac hypertrophy and increased vascular tension, which are essential to the occurrence of proper excretion in chronic renal disease, requires that the amount of protein in the food should not be too rigidly limited. On the other hand, an undue increase of blood pressure, which may be induced by a too highly nitrogenous diet, and especially, perhaps, by one which is rich in extractive matters, is itself a source of danger, as predisposing to arterial degeneration and to apoplexy.

It will be obvious from all this that the proper dietetic management of a case of chronic Bright's disease often requires careful steering. If there be too little protein in the food, cardiac compensation may break down and uræmia result; if there be too much, the patient is exposed to all the risks and inconveniences of excessive vascular tension. For the former reason milk is not suited to constitute the sole source of protein in the diet of such cases; for the latter the excessive use of meat is also to be deprecated. As a general rule, perhaps, one may say that the more the secreting tubules, as opposed to the glomeruli, are involved, the less protein should the food contain;

¹ See also Senator, *Berlin. Klin. Woch.* 1899, xxxvi. 990.

² *Med.-Chir. Trans.*, 1879, lxii. 243; see also Prior, *Zeit. f. Klin. Med.*, 1891, xviii. 72.

but for the majority of cases the most appropriate diet is that recommended for gout—*i.e.*, one which is only moderately rich in protein, and that derived largely from vegetable sources, and from which spices, soups, and all preparations containing the extractives of meat are excluded.

In cases of subacute and chronic parenchymatous nephritis in which dropsy is a prominent feature, the use of the so-called 'salt-free' diet is often of service. It is described in detail on p. 550. In cases of protracted dropsy in chronic parenchymatous nephritis it is sometimes found that great benefit accrues from deliberately increasing the amount of protein in the food, with the object of raising the osmotic pressure of the blood by making good its poverty in albuminous substances. At the same time the amount of fat in the diet should be restricted in order to lessen the blood lipoids. It is on these principles that the **Epstein Diet**¹ is constructed. It consists of fish, lean meat, lean ham, whites of eggs, oysters, lentils, peas, rice, oatmeal, bananas, skimmed milk, tea, coffee, and cocoa; salt is given to taste. The Calorie value of the diet is from 1,280 to 2,500, and it contains from 120 to 240 grammes of protein, 20 to 40 grammes fat, and 150 to 300 grammes carbohydrate. The total fluid allowed is from 1½ to 2 pints. Excellent results from the use of such a diet have been reported in many cases.²

Finally, a word about the use of fluids in renal disease. It was laid down as a rule by Bamberger that in no form of kidney affection should fluids be restricted unless diarrhoea were present. This dictum has been criticized by Von Noorden,³ who states that if dropsy has occurred, and the secretion of urine is scanty, great benefit may be derived from limitation of fluids, especially if there be cardiac dyspnoea and threatening heart failure. He says that long-continued observations by himself and his assistants have quite failed to show that the products of nitrogenous waste are not well excreted under such a plan, and cites several cases in which it wrought great improvement. On the other hand, he recommends that if diuresis has already set in fluids should be freely allowed, even although oedema be still present. It must remain for further clinical experience to substantiate these conclusions, but in cases of high vascular

¹ A. A. Epstein, *Amer. Journ. Med. Sci.*, November, 1917; and *Journ. Amer. Med. Assoc.*, August 11, 1917.

² See Allbutt, *Brit. Med. Journ.*, October 12, 1918; Galloway, *ibid.*, October 4, 1919; Box, *ibid.*, March 13, 1920; Symes, *ibid.*, April 10, 1920.

³ 'Diseases of Metabolism and Nutrition,' Part II., Nephritis. English edition (Bristol: John Wright and Co., 1903).

tension, at all events, the sudden entrance of a considerable quantity of fluid into the circulation must always be apt to be injurious, and in such circumstances, whether the total daily supply of fluids be limited or not,¹ it is wise to forbid the consumption of a large quantity at one time.

The habitual use of alcoholic beverages should be avoided as far as is practicable in cases of chronic nephritis, unless they are imperatively indicated for the sake of the heart. 'A sufferer from atrophic nephritis,' says Von Noorden,² 'should be instructed by his physician that alcohol, unless prescribed as a medicine, is for him a dangerous poison. If he insists upon taking it, he does so at his own risk.'

In practice these principles may be applied in the following rules :

DIRECTIONS FOR DIET IN CHRONIC NEPHRITIS.

1. The following are harmful and should be absolutely avoided :
 - Soups made from meat ; gravies ; sauces ; spices (e.g., mustard, pepper, ginger, curry, nutmeg or cloves).
 - Peas, beans, and lentils.
 - Radishes, celery, asparagus, rhubarb, onions.
 - Alcoholic beverages.
2. Sugar and fruits may be taken freely.
3. Tea and coffee should be taken in strict moderation.
4. The animal ingredients of the diet should be restricted to 1 egg, 1 pint of milk, and one helping (3 ounces) of meat, fowl, or fish daily.

¹ Von Noorden recommends that the total amount of fluid allowed in the diet in cases of chronic nephritis should not exceed $1\frac{1}{2}$ litres (about 2 pints) per day. He goes so far as to say that in many cases of contracted kidney such a restriction may save life. The prevailing clinical opinion now, however, is that in cases with salt retention and dropsy, fluids should be restricted, but where renal efficiency is low and nitrogen is being retained, fluids should be allowed freely.

² *Op. cit.*

7. Diseases of the Nervous System.

Dietetic means are of comparatively little value in the treatment of nervous diseases. In most of such cases the food must be adapted to the condition of the patient's other organs. In many cases of **neurasthenia** it is important to improve the state of the patient's nutrition by adopting the plan of feeding already described in the section on 'fattening up' (p. 503), and for all nervous subjects fat seems to be one of the most important nutritive constituents of the food, and it is often important to preach to such patients what has been described as 'the gospel of fatness.' The question of the most suitable diet in cases of **epilepsy** has led to much discussion, some writers recommending abstention from meat in that complaint, whilst others put a strict bar upon the use of alcohol.

Schloss¹ has investigated the subject afresh, and concludes, as the result of his clinical experiments, that the nature of the diet adopted has no appreciable influence either on the number or the severity of the fits. Nor did he find that the use of alcohol could be shown to be in any way harmful. The value of reducing the amount of common salt in the diet of epilepsy and of substituting for it bromide preparations has also been insisted upon by some writers.² Schloss, in investigating this point, found that by selecting a diet containing but little sodium chloride he could reduce the consumption of that salt to about 30 grains a day, replacing it by 60 grains of mixed bromides. Under this treatment the fits became fewer and less severe, but the patient steadily went down in weight and strength.

Aldren Turner³ believes that a purin-free diet (p. 545) is sometimes useful in epilepsy, especially in recent cases in which the seizures are of the major variety. It is certainly always worth trying.

In cases of **chorea** the diet should be of a fattening character (p. 503), cream and other fat-containing foods being given liberally. Where fluid food can alone be taken, milk, beaten-up eggs, and strong soups should form the basis of the diet. These constituents

¹ 'Ueber den Einfluss der Nahrung auf den Verlauf der Epilepsie,' *Wiener Klin. Woch.*, 1901, xiv., No. 46.

² See Bálint in *Berlin. Klin. Woch.*, 1901, xxxviii. 617. A review of other results will be found in an article by Dr. Purves Stewart in the *Med. Annual* for 1904 (p. 314).

³ *Practitioner*, 1906, lxxvi. 476.

may be enriched by the addition of casein preparations, cream, and some of the numerous cereal foods.

In **Graves' disease** there is some reason to believe¹ that meat is harmful, and a vegetarian or lacto-vegetarian diet gives the best results. The food should be nourishing and contain plenty of fat. Alcohol, tea and coffee should be avoided.

In the treatment of **headaches**—especially of the periodic migrainous or bilious variety—diet is sometimes of great help. In certain individuals, particular articles of food may apparently cause such headaches by acting as direct poisons. Amongst such articles are tea, sugar and eggs. More often it is necessary to make radical alterations in the diet as a whole. In well-nourished patients a decided limitation of the 'carbonaceous' foods as recommended by Dr. Hare (for details see p. 546) is often successful. Others do well—for a time at least—on a purin-free diet (p. 544). In yet others, vegetarianism, or at all events a great reduction in the intake of animal protein (meat) on the lines advocated by Chittenden, gives good results. In every case it is necessary to individualize, and to take into consideration the condition of the vital organs and the state of the patient's general nutrition, for in some cases—particularly when the headache is of a neuralgic character—a cure only results when the level of nutrition has been raised by a judicious course of fattening (p. 503).

8. Diseases of the Skin.

There are four ways in which diet may conceivably influence the skin:² (1) By affecting general nutrition; (2) reflexly from the alimentary canal; (3) by giving rise to the absorption into the blood of irritating or decomposition products; (4) by the elimination through the skin of certain constituents of the food.

It must be admitted, however, that when we come to use dietetic methods in the actual treatment of cutaneous disorders, we find ourselves greatly hampered both by our ignorance of the precise part played by diet in any given case, and by the always unknown factor of personal idiosyncrasy. So much is this the case that it may be said without fear of contradiction that there are but few diseases of the skin in which treatment by diet is of much value, and that the potentialities of this line of attack are much less promising than patients generally believe.

¹ Hanna Thomson, *Amer. Journ. Med. Sci.*, 1908, cxxv. 313.

² Walter Smith, *Brit. Journ. of Dermat.*, 1898, vii. 328.

In the great majority of cases of skin disease, therefore, either no special rules of diet are required, or they must be drawn up with reference to the patient's general condition without regard to the state of the skin. There are a few cutaneous diseases, however, in which diet may be of some direct help, and these may be briefly considered.

Eczema.—In very acute cases in which the patient is really ill, an exclusively milk diet may be required for a time, and in any case the more marked the local inflammatory signs are, the simpler should the diet be. In chronic cases it is customary to forbid sugar and to recommend a liberal use of green vegetables, but in both instances on no very satisfactory grounds. An excess of salt also appears to be injurious. On the whole, the diet in chronic eczema should conform to the principles of 'simplicity and temperance,' and may, in details, be the same as for chronic gout (p. 510). Alcohol is usually harmful.

In **psoriasis** various 'systems' of diet occasionally meet with success. Bulkley¹ recommends absolute vegetarianism, forbidding even milk and eggs, and says he has seen the worst cases disappear under such a plan, whilst *per contra* the quite opposite regimen of meat and hot water only,² or an exclusively milk diet, has proved successful in the hands of others. In the majority of cases, diet has probably little or no influence.

In **rosacea** the diet should be arranged to meet any form of dyspepsia which may be present (p. 521), but alcohol, tea, coffee, spices, and anything which causes flushing of the face must be rigidly excluded.

In **pruritus**, especially of the anus or vulva, all highly-seasoned, salted, or preserved foods should be avoided, besides alcohol and coffee, and the diet restricted to the white meats, toast, green vegetables, and light milk puddings. Should diabetes be present, the dietetic indications are, of course, the same as for that disease (p. 488).

In **urticaria** much may be effected by diet if one can discover—not always an easy task—the peccant ingredients of the food. Amongst the most frequent offenders are shell-fish, mushrooms, pickles, pork, eggs, cheese, oatmeal, strawberries or other fruits, and sour wines, but almost any article of food may cause it if an idiosyncrasy be present. I have also known patients to be cured by adopting vegetarianism for a time.

¹ *Journ. Amer. Med. Assoc.*, 1908, February 22.

² Parkes, *Lancet*, 1874, i. 722; and Malcolm Morris *Practitioner*, 1906, lxxvi. 575.

In concluding this section, one cannot do better than quote the wise words of an eminent dermatologist:¹ 'After all, it is in comparatively few cases of skin disease that the diet is really of any particular importance. . . . Put not your faith in printed dietaries, or indeed in any general formularies. Above all, remember that the patient has larger and better opportunities of observation than the doctor, and, if he is a person of ordinary intelligence and self-control, he should be trusted. The doctor who attempts to dictate as an oracle in the matter of diet is like Lord Foppington's bootmaker, who insisted that he knew better than his client whether or not the shoe pinched.'

¹ Malcolm Morris, *loc. cit.*, p. 584.

CHAPTER XXIX

SOME DIETETIC 'CURES' AND 'SYSTEMS'

IN the earlier part of this book reference has been made to the so-called milk (p. 130), whey (p. 132), koumiss (p. 143), and grape (p. 256) 'cures.' In the present chapter I propose to deal briefly with some of the more elaborate 'systems' of diet which are sometimes useful in the treatment of disease. That such systems are occasionally of great therapeutic value no one can deny, but they must be used discreetly, bearing in mind the dangers and fallacies inherent in all attempts to treat disease on a 'system,' regardless of the peculiarities of the individual case, and remembering that no such system can ever be a panacea, but is at best of restricted, and often only of temporary, value. The reckless and uncritical advocacy of the faddist can only serve to bring such systems into disrepute.

VEGETARIAN AND LACTO-VEGETARIAN DIET.

In a previous chapter (p. 172) the question of vegetarianism was discussed in detail, and the conclusion arrived at that it was not a form of diet which is to be unreservedly commended for healthy persons. None the less, as a mode of treatment in certain cases of disease, such a regimen is deserving of the careful consideration of the medical profession, and all the more that hitherto it has been mainly exploited by the large body of 'amateur' practitioners.

There are certain well-recognized peculiarities and properties of a non-flesh diet which justify the expectation that it will prove of use in some morbid states. In the first place, such a diet is comparatively free from the purin-bodies, the share of which in the production of gout has already been discussed (p. 509), besides containing almost always less total protein than a mixed diet. In the second place, a diet from which flesh is excluded, and which contains a large proportion of milk, tends greatly to restrain the process of putrefac-

tion in the intestine. Now, there is some reason to believe that certain obscure conditions of general ill-health, and in particular some cases of neurasthenia, are produced and maintained by the absorption of such putrefactive products. In the third place, such a diet is peculiarly rich in mineral salts, and although the part played by these in metabolism is at present but ill-understood, there is yet reason to believe that by altering the 'balance' of the salts in the body nutrition may sometimes be influenced for good. In the last place, a diet which is of mainly vegetable composition leaves a large residue in the bowel, and so tends to counteract the prevailing modern tendency to constipation, with all its attendant evils.

Much careful observation and clinical experiment will certainly be required before we are able clearly to discern exactly in what cases a diet of this sort is likely to be of benefit, but meantime the following list of diseases in which there is at least presumptive evidence that a vegetarian or lacto-vegetarian regimen exercises a curative influence may be tentatively put forward.¹

- (1) Corpulence complicated by constipation in middle life.
- (2) Certain cases of alcoholism.
- (3) Some forms of functional dyspepsia and intestinal affections of nervous origin.
- (4) Idiopathic neuralgias and those having a gouty basis.
- (5) Headaches and other disorders dependent on constipation in neurasthenic, hysterical, and epileptic patients.
- (6) Conditions of abnormal irritability of the heart of nervous origin and in exophthalmic goitre; but not heart-weakness due to arteriosclerosis and myocarditis.
- (7) Many cases of nervous insomnia.
- (8) Some varieties of disease affecting the skin.

It is almost always advisable to make the change from an ordinary diet gradually, and in many cases it is inadvisable to continue the vegetarian plan for longer than six weeks at a time.

THE PURIN-FREE DIET.

Purins are a series of bodies which contain the nucleus C_5N_4 , and which on oxidation yield two molecules of urea. They may be classified as: (1) *Oxy-purins* (hypoxanthin, xanthin and uric acid); (2) *amino-purins* (adenin and guanin); (3) *methyl-purins* (theobromin and caffenin).

The purins of the food (exogenous purins) are taken in the

¹ See L. Kuttner, *Berliner Klinik*, January, 1902, and Albu, 'Die Vegetarische Diät' (Leipzig, Georg Thieme, 1902), p. 130.

following forms: (1) *Methyl-purins* in tea, coffee and cocoa; (2) *free purins*, such as xanthin and hypoxanthin, in meat extract; (3) *bound purins* in the nucleo-proteins of many animal and some vegetable foods.

Foods may be classified according as they are rich in purins, poor in them, or free from them, as follows:

1. *Rich in purins*: Sweetbread, liver, beef, pork, mutton, chicken, veal, salmon, halibut, and plaice.

2. *Poor in purins*: Potatoes, onions, oatmeal, the pulses, turnips, carrots, parsnips, asparagus, rhubarb, sea-kale, spinach, dates, figs, codfish, and sole.

3. *Free from purins*: Milk, eggs, cheese, butter, sugar, white bread, rice, tapioca, cabbage, cauliflower, lettuce, macaroni, strawberries.

Amongst *beverages*, tea, coffee, and cocoa, and malt liquors contain purins; wines and spirits are free from them.

A diet which is practically purin-free may therefore be constructed by observing the following rules:¹

DIRECTIONS FOR A PURIN-FREE DIET.

1. The things to be avoided are:
 - (a) All flesh foods (meat, fish, fowl, game, etc.) and articles derived from them (*e.g.*, soups, sauces, gravies).
 - (b) Peas, beans, lentils, oatmeal, asparagus, onions.
 - (c) Tea, coffee and malt liquors.
2. The diet should be composed of vegetable foods (except those mentioned above), milk, cheese and eggs.

The following is suggested as a daily menu:

Breakfast: Eggs, the fat of bacon (avoiding all lean), bread or toast, milk flavoured with cocoa or a *dash* of coffee or tea. Any fruit, stewed or fresh.

Luncheon or dinner: Soup made from vegetables (except those mentioned above), with the addition of milk, if desired, and thickened with some farinaceous preparation or grated cheese; one of the Italian dishes—*e.g.*, risotto, macaroni, spaghetti, or polenta; potatoes in any form; any simple pudding or stewed fruit; cheese; salad.

The change to such a diet should be made gradually. For a week or two the non-nutritious purin-containing articles—*e.g.*, tea, coffee, soups, beef-extracts, gravies—should be avoided, and meat and fish taken only once a day. After this probationary period is over the more strict diet may be adopted.

The advantages of what was practically a purin-free diet in cases of gout were pointed out long ago by Dr. George Cheyne,² but in

¹ The construction of such a diet is facilitated by a study of various *cookery*-books—*e.g.*, 'Vegetarian and Simple Diet,' by Kenney Herbert (Sonnenschein), and 'The Apsley Cookery-Book' (J. and A. Churchill).

² 'The English Malady' (London, 1733).

recent times, and under its modern title, it has been specially advocated by Dr. Haig.¹ The benefits derived from its use in certain cases of disease are ascribed to the alleged toxicity of purins, which are believed to produce the following amongst other diseases: Chronic and irregular gout in all its manifestations, chronic 'rheumatism,' migraine and periodic headaches, asthma, bilious attacks, epilepsy, catarrhs, neurasthenia and general ill-health of indefinite nature.

It would be going far beyond the province of this book to discuss in detail the evidence for and against the harmfulness of the purin bodies in food-stuffs,² but it may be said that whilst there can be no doubt of the fact that a purin-free diet is capable of exerting a curative effect in some at least of the above-mentioned maladies, there is equally little doubt that the therapeutic claims made for it by some of its more intemperate advocates cannot be substantiated. There is certainly no reason to believe that purins are 'poisonous' in any real sense of the term to the vast majority of mankind, and, on the other hand, it is quite possible that some of the good effects which a purin-free diet is capable of producing are to be ascribed to something other than its poverty in these chemical compounds. As it is quite conceivable, however, that some persons have a metabolic idiosyncrasy to purins, and that in such they produce disease, the purin-free diet is always worth trying in chronic and intractable cases of the type already referred to. It will often be found, however, that even in such persons freedom from symptoms is not permanent, but that the morbid manifestations recur after a time, although perhaps in a milder form.³ In any case, the change to such a diet should always be made cautiously, and it is not often advisable to continue it for long in its strict form, as otherwise digestive troubles and impairment of the general health are apt to result.

DR. HARE'S SYSTEM.

Dr. Francis Hare⁴ believes in the possibility of the accumulation in the blood of an excess of 'fuel' or 'carbonaceous' material. He

¹ 'Diet and Food' (London: Churchill), etc.

² The question is discussed in the following amongst other papers: Potts, 'The Advantages of a Purin-Free Diet,' *Lancet*, 1905, i. 1636; 'Purin-Free Diets,' *Brit. Med. Journ.*, 1909, i. 110; Chalmers Watson, 'Has a Purin-Free Dietary any Special Therapeutic Value,' *ibid.*, 1907, ii. 1759; Bryce, 'The Limitations of a Purin-Free Diet,' *ibid.*, October, 31, 1908.

³ See Bryce, *loc. cit.*

⁴ 'The Food Factor in Disease' (Longmans, 1905), and 'The Dietetic Treatment of Certain Diseases in the Well-nourished and Corpulent' (*The Medical Magazine*, 1907, xvi. 722).

terms this a state of *hyperpyræmia*, and attributes to it the occurrence of many periodic disorders, such as migraine, bilious attacks, and asthma. The hyperpyræmic state can be prevented by reducing the intake of carbonaceous food, with the consequence that the periodic disorder disappears.

He begins by placing the patient on a small, mainly protein diet, consisting, say, of 8 to 12 ounces of cooked lean meat or fish, with $1\frac{1}{2}$ ounces of bread or toast and a little butter; green non-starchy vegetables are permissible, also tea and coffee with a little milk but no sugar. Such a diet is usually accompanied by loss of weight. The loss is carefully estimated by frequent weighings and by slowly adding to the amount of carbohydrates and fats, preferably by cautiously increasing the allowance of bread, butter, and milk a diet is arrived at under which the weight remains stationary and carbon equilibrium is being maintained on a minimum intake. In arriving at this minimum exactitude is indispensable; the scale of diet should be fully written out and the ingredients weighed.

If one is treating a case of migraine it is advisable to begin the diet about a fortnight before the next attack is expected, and after one headache period has been passed to increase slowly the amount of starchy food until the weight is stationary.

Without accepting the theoretical considerations upon which this system of treatment is based one may freely admit that it gives excellent results in many of the conditions referred to, and as it is easy to carry out it is often a valuable resource. Such a regimen, however, is only suitable in well-nourished persons, and it is in these that its most striking effects are obtained.

EXCLUSIVE PROTEIN DIET.

In this system, which is better known as the Salisbury cure,¹ the diet consists of lean meat and hot water only. Such a diet may be spoken of as an exclusively protein one, for although there is always a certain proportion of fat even in lean meat, yet the amount for practical purposes is negligible. This system has been recommended in the treatment of chronic articular gout, some diseases of the skin—*e.g.*, psoriasis—and in certain intractable forms of dyspepsia, especially when associated with atonic dilatation of the stomach. The following is a description of the technique of the diet as given by one of its more recent advocates:²

¹ Salisbury, 'The Relation of Alimentation and Disease,' New York, 1895.

² Ernest Young, *The Clinical Journal*, 1908, xxiii. 55.

'The basis of the diet is thoroughly cooked minced lean beef (so prepared that all gristle and the greater part of the connective tissue are removed) and hot water. (Minced mutton or chicken may be substituted occasionally for variety, but bulk for bulk neither is so nourishing as the beef.)

'The minced beef is given three times a day, with a five-hourly interval between each meal. The best hours for meals are 8.30 a.m., 1.30 p.m., and 6.30 p.m. In any case the last meal should not be later than 7 p.m.

'The hot water is given four times a day, one and a half to one and a quarter hours before each meal, and three and a half hours after the last meal. The water should be *sipped slowly* at a temperature of about 120° F.—roughly that at which tea or coffee is usually taken. The quality of the water is an important factor, and if at all hard distilled water must be used.

'The quantity of meat at each meal varies from 2 ounces upwards, the quantity of each portion of hot water being a pint, or less, according to the nature of the individual case.'

The following details as to the preparation of the diet (from the same author) may be of practical help:

The diet may be taken in the form of beef mince or beef cakes, the former being rather more digestible but less satisfying than the latter.

Both should be prepared from 'topside' steak, preferably from the centre of the round of beef.

1. *The Beef Mince*.—Take a steak, not less than an inch thick, free it from fat, place in a frying-pan—previously rubbed with a little butter to prevent sticking—and cook quickly (turning occasionally) over a clear, sharp fire until it is almost *half done*. Allow it to cool, then cut into strips and pass three or four times through an 'Enterprise' mincer. Place the minced meat in an enamelled or aluminium saucepan, add a little water (about a teaspoonful to 1 ounce of meat is the average quantity) and beat to a smooth, stiff pulp with a wooden spoon; it must never be watery. Place the saucepan on an asbestos cooking-mat upon a cool part of the stove and cook slowly, stirring and turning over the mince constantly until the red colour disappears and it is thoroughly brown. This will take from fifteen to twenty minutes for a small quantity. If properly prepared at a gentle heat, the mince will be quite smooth and of the consistency of soft dough. If it is granular, it shows it has been cooked too quickly, and must be rejected.

2. *The Beef Cakes*.—Pass strips of *raw* steak three or four times through the mincer. Place the minced meat on a plate, flatten out with a fork, and add a little water. By means of two forks quickly shape the meat into a round, flat cake about 1 inch thick, touching the meat as lightly as possible, just sufficient to make it hold together. Place the cake in an 'Enterprise' grill, previously rubbed on both sides with a little butter. Hold the grill about 8 inches above a sharp, clear fire, turning it about every ten seconds until the cake is cooked. The time required for cooking is seven or eight minutes.

Condiments, such as pepper, salt, and mustard, may usually be allowed, unless hyperchlorhydria is a prominent feature.

If the patient complains much of hunger, a few spoonfuls of beef-tea or a piece of unsweetened chocolate may be given two and

a half hours after each meal. A cup of clear tea may be given in place of some of the afternoon hot water.

The theoretical considerations on which the exclusive protein diet is based cannot be considered here, and, indeed, they are largely speculative in nature, but some reference to the subject will be made later. Meanwhile it need only be said that the treatment undoubtedly yields good results in some of the chronic disorders of digestion and nutrition already indicated, but it is only in exceptional cases that it is required, and in any event it is not advisable to continue such a regimen for longer than six weeks at a time.

The reader may have noticed that vegetarianism, the purin-free diet, Dr. Hare's system, and, to some extent, the 'exclusive protein diet' are all recommended by their supporters in very much the same class of disorders, and it may seem strange that systems so opposed should be capable of curing identical diseases. In these circumstances one naturally looks for some peculiarity common to all the systems which might explain this apparent contradiction. I would venture to suggest that this may be found in the fact that they all tend to promote a more complete oxidation of the proteins. Such a result may be brought about either by lessening the total intake of protein or by diminishing the protein spacers (especially the carbohydrates) which interfere with their complete combustion. Now, in vegetarianism, as we have seen, the total amount of proteid in the diet is apt to be low, and the same is true, in practice, if not in theory, in the case of the purin-free diet; in Dr. Hare's system, on the other hand, and still more in the case of the exclusive protein diet, the protein spacers are greatly reduced. Whichever of these plans is adopted then, it is probable that the oxidation of the protein of the food is likely to be more complete than is the case with an ordinary abundant mixed diet. It will be remembered that one of the advantages claimed for the Chittenden diet standard is that it tends to promote this complete utilization of proteins, and it is noteworthy that the advocates of Chittenden's plan claim that it also is capable of preventing or curing much the same class of diseases as those for which the systems of diet dealt with above are recommended.

It is possible, too, that *any* marked alteration in diet is capable of effecting an improvement in general health, just as change of air does, and in ways that are as ill understood.

ZOMOTHERAPY.¹

By the term 'zomotherapy' (*Zωμος*, meat-juice) is meant treatment by raw meat or raw meat-juice. It was first introduced by Professor Charles Richet in 1900,² and was based on the successful results obtained by feeding dogs which had been inoculated with tuberculosis on raw meat, although Fuster had recommended a diet of raw meat and alcohol in tuberculosis as far back as 1865. Subsequent experiments showed that the beneficial properties of raw meat reside in the muscle-juice and not in the fibres, and, further, that the benefit derived is not to be ascribed to hyper-alimentation, inasmuch as (in dogs) a daily dose of 50 to 100 c.c. of the juice are sufficient to give the desired results. The *modus operandi* of raw meat-juice in the cure of tuberculosis is not understood, but it has been suggested either that it contains a specific 'tonic' and stimulant, or that it acts in virtue of the presence of some antitoxic substance.

Zomotherapy is indicated in cases of anæmia, neurasthenia, debility, convalescence, and latent, incipient, or active tuberculosis. In carrying it out the juice should either be obtained fresh by expression³ from the best rumpsteak or Carnine Lefrancq (p. 101) may be used instead. The fresh raw juice may be given in quantities of 3 ounces a day and upwards, preferably in tepid beef-tea. The dose of Carnine Lefrancq is from 1 to 6 tablespoonfuls daily, given alone or mixed with any other liquid (except beef-tea), either cold or slightly warm.

SALT-FREE DIET.

The average amount of common salt in an ordinary diet is about 17 grammes per day, and although it is impossible, even were it desirable, to construct a genuinely 'salt-free' diet, yet by a judicious selection of foods it is easy to reduce the daily intake to about 2 grammes. Such a limitation of salt is of use in the treatment of dropsy, particularly the dropsy of chronic parenchymatous nephritis. It was shown by Widal—to whom much of the credit of introducing the salt-free diet is due—that a chronically inflamed kidney is

¹ See Héricourt, 'Zomotherapy.' Paris: J. Rueff.

² *Comptes Rendus de l'Académie*, 1900, cxxx. 605.

³ The 'Hercules' Meat-juice Press gives the best yield. It can be obtained from Messrs. Shoolbred, Whiteley, or Kent (High Holborn). Philip ('Zomotherapy in Pulmonary Tuberculosis,' *The Practitioner*, 1905, lxxiv. 14) also exhibits zomotherapy in the form of 'raw-meat soup' prepared as follows: Take $\frac{1}{2}$ pound of finely-minced *fresh* meat, and mix in a bowl with sufficient milk to produce a thick, uniform paste. Immediately before serving add $\frac{1}{2}$ pint of milk at 150° F. In place of milk, the soup may be made in similar fashion with stock of beef, or chicken, or veal.

incapable of excreting common salt freely. The salt is therefore retained in the body, and in order that the normal composition of the body fluids may be maintained water is kept back also, with the result that dropsy sets in. When the amount of salt in the food is reduced the percentage of it in the blood gradually falls, the salt which has been stored up in the dropsical effusion is drawn upon to make good the deficiency in the blood, and with its withdrawal the dropsy subsides. Such, put briefly, is the rationale of the plan and of its success in cases of chronic parenchymatous nephritis,¹ and also, though less conspicuously, in cardiac dropsy,² and in the ascites of cirrhosis³ there can no longer be any doubt.

A comparatively salt-free diet is not difficult to construct. It must, of course, contain no added salt. Ordinary bread, salt butter, sea-water fish, dried, smoked, salted and preserved foods and sauces and pickles must be avoided. Soups should be made from vegetables and milk. Bread must be baked without salt, or its place taken by home-made scones.

The following table, which shows the amount of salt per 1,000 parts in some common articles of food, will be of assistance in making a selection:⁴

Ham	18	Fresh butter	1'0
Cheese	15	Peas	0'6
Bacon	10	Meat	0'3-1'0
Bread	8-10	Potatoes	0'5
Sea-fish	5'4	Fresh-water fish	0'48
Milk	1'5-2'5	Fruit	0'03-0'2
Eggs	1'6	Rice	0'02
Lentils	2'3		

The following may be regarded as a typical bill of fare:⁵

Breakfast: An egg, bread without salt, fresh butter, tea or coffee and cream.
10 a.m.: A glass of milk.

Dinner: Chicken or fresh-water fish; potato; jelly.

3 p.m.: A glass of milk.

Supper: An egg, chicken, or fresh-water fish; bread without salt; custard; fresh butter.

8 p.m.: A glass of milk or water.

SOUR MILK TREATMENT.⁶

Curdled milk has long entered largely into the diet of the inhabitants of many countries in the Near East—e.g., Turkey, Roumania,

¹ Fowler, *Med. Press*, October 13, 1908.

² Mendel, *Münch. Med. Woch.*, 1909, lvi. 433, 516.

³ Vasoin, *Archiv f. Verdauungs. K.*, 1905, xi. 633 (abstract).

⁴ See also Strauss, *Praktische Winke für die Chlorarone Ernährung*. Berlin: S. Karger, 1910.

⁵ Peabody, *Med. Record*, 1907, lxxi. 381.

⁶ For further details see Herschell, 'Soured Milk and Pure Cultures of Lactic Acid Bacilli in the Treatment of Disease' (Glaisher, 2nd edition, 1909), and 'Lactic Acid Bacilli Preparations' (W. Martindale, 10, New Cavendish Street, W.)

Bulgaria, and Serbia—the best-known preparation being the Bulgarian yaghourt, or yohourth, in which the souring is brought about by the *Bacterium Caucasicum*, or Bulgarian bacillus. Metchnikoff¹ suggested the use of this preparation in the treatment of disease, and Cohendy² first proved the possibility of acclimatizing the Bulgarian bacillus in the intestine, and of lessening intestinal putrefaction by so doing. The Bulgarian bacillus has the advantage over other lactic-acid producing organisms for this purpose, in that it is both more resistant and more active.

Since its introduction this method of treatment has attained a wide popularity, and soured milk is now largely used, either in a ready-made or home-made form. It must be pointed out, however, that many commercial preparations of soured milk either do not contain the Bulgarian bacillus at all, or contain it in a very impure form, and the same is true of the many tablets or liquid cultures which are sold for preparing it at home, and which are designed for the direct inoculation of the intestine.³ That some of the impurities which these preparations contain may produce harmful results there can be no doubt, and it is therefore advisable that the soured milk should always be prepared at home, and from cultures of guaranteed purity.

The time has not yet come for a final pronouncement on the value of soured milk as a therapeutic agent, but it has been recommended in cases of chronic ill-health without obvious cause, in neurasthenia and intestinal affections—*e.g.*, colitis, fermentative diarrhoea, constipation—besides gout, arterial sclerosis, and some skin diseases. As regards many of these affections it may be pointed out that there is little or no proof that they are really the result of intestinal putrefaction, and any improvement which soured milk may produce in them is probably to be ascribed to the fact that it provides an easily-digested form of food, and so improves the patient's nutrition.⁴ On the whole there can be little doubt that the treatment has been much overdone, and that in consequence it will before long fall into perhaps unmerited disrepute. In cases of hyperchlorhydria and chronic acid gastritis it is always contraindicated.

¹ 'The Prolongation of Life.'

² *Comptes Rendus de la Soc. de Biol.*, 1906, lx. 558, 602, 872.

³ See report of a discussion on 'The Lactic Acid Treatment,' *Proc. Roy. Soc. of Med.*, January, 1910.

⁴ See Rosenberg, *Archiv f. Verdauungsk.*, 1909, xv. 458.

CHAPTER XXX

**ARTIFICIAL AND PREDIGESTED FOODS AND
ARTIFICIAL FEEDING**

IN this chapter we shall describe some patent and artificial foods not yet dealt with, and consider the methods of administering food otherwise than by the mouth.

1. Artificial Foods.

The objects of artificial foods may be said to be either (1) to present a maximum of nourishment in a minimum of bulk, or (2) to enable one easily to enrich the diet in respect of certain of its chemical constituents.

In regard to the former of these objects, it is well to realize at the outset what **degree of concentration of food** is chemically possible. Let us take first the case of the **proteins**. Lean meat may be regarded as the type of a natural protein food. It contains about one-fifth of its weight of that constituent, the rest being chiefly made up of water. If one drives off all the water from 5 ounces of meat, there will be left behind about an ounce of what is practically pure protein. Now, this may be regarded as the maximum degree of concentration of which protein food is capable. In other words, an ounce of any artificial protein food can never represent more than 5 ounces of lean meat. A more concentrated protein food than that is a chemical impossibility. One can realize from this the absurdity of such preparations as beef-lozenges. Even did these consist of pure protein (which they never do), it would require 1 ounce of them at least to be equal in food value to 5 ounces of fresh meat, so that the amount of nutriment contained in one lozenge must be very small indeed.

Or take, again, the case of the **carbohydrates**. There is no form of carbohydrate food more concentrated than sugar. Any fluid or semi-fluid carbohydrate preparation must inevitably be of lower nutritive value than sugar, for it contains more or less water, the food value of which is nil. Such preparations as malt-extracts, therefore, can never add to the diet as much carbohydrate as an equal weight of ordinary sugar.

The same is true of **fats**. No artificial preparation can have a higher food value than pure olive-oil, which contains no water, or dripping, from which all the water has been driven off by heat. Even ordinary butter contains four-fifths of its weight of pure fat.

There are, then, distinct limits beyond which the concentration of foods cannot be carried, and the idea that 'food tabloids' might be prepared, one or two of which would be the equivalent of an ordinary meal, is seen to be an impossible dream. At the most, all that the maker of concentrated artificial foods can hope to do is to drive off from the natural food the excess of water which it contains, and even then most, if not all, of the original water must be returned to the food before it can be eaten.

It may be questioned, too, whether the use of highly concentrated foods is physiologically defensible. The digestive organs are not constructed for the disposal of foods in an extremely compact form. Such forms of nutriment make large demands upon the secretory powers of the stomach, and are apt to be irritating to the digestive organs, in addition to which the total absence in them of 'ballast' renders them unable to supply an adequate stimulus to the peristaltic movements of the intestines. As exclusive foods, therefore, such preparations are eminently unsuitable.

The second object of these substances, that of enabling one to **enrich the diet in certain ingredients**, is more legitimate. Here the artificial food is used simply as an accessory to supplement the lack of protein, carbohydrate, or fat in other articles of diet. Their small bulk is here a decided advantage, for it enables them to be added to fluid foods without appreciably increasing the total amount of material to be swallowed, and in many cases of illness this is a desirable thing to do.

One may conclude, then, that concentrated foods are only to be used as accessories, and that they have no legitimate place in the dietary of health.

In cases of sickness, however, they have a definite but limited sphere of action. In these circumstances, when appetite is in abeyance, it is often a question not so much of getting the patient to take much nourishment as of persuading him to eat at all. It is then that the artificial foods serve a useful purpose, for they can be varied to suit the caprices of the patient, and though the amount of actual nourishment which they yield may be small, they may yet kindle a desire for ordinary foods. The value of any artificial preparation in such a case is not to be estimated by the amount of energy it yields, so much as by its æsthetic qualities and the degree to which it pleases the patient. Suggestion, in fact, plays a large part in bringing about whatever good results artificial foods are capable of producing.

ARTIFICIAL PROTEIN FOODS.

1. **Undigested**—(a) *Of Animal Origin*.—Probably the best of the undigested protein foods are now derived from casein, the chief protein of milk. In a previous chapter (p. 143) most of these have been described (Plasmon, Casumen, Protene flour, etc.). They have the advantage of being colourless, tasteless, and readily soluble, so that they can easily be added to other foods, besides which they are digested without difficulty and are very completely absorbed.

Of the artificial protein foods derived from meat, most belong to the predigested class to be considered immediately. Such a preparation of dried meat as **pemmican**, however, may fairly be regarded as belonging to this group, and the same may be said of the dried meat prepared by the Gye and other processes (see p. 165). As has been pointed out elsewhere (p. 108), anyone can, with a little trouble, prepare for himself a powder of dried meat, the nutritive value of which is as high as that of any artificial preparation.

(b) *Of Vegetable Origin*.—The chief vegetable protein foods are **Aleuronat**, **Legumin**, **Roborat**, **Glidine**, and **Plantose**. The first is a special preparation of gluten containing 80 to 90 per cent. of protein. It is a yellowish-brown powder, almost insoluble in water, and can be conveniently used as an addition to semi-solid foods. It is largely

employed, also, in the feeding of diabetics, and has the advantage of being fairly cheap.

Legumin (vegetable casein) is the chief protein of pulses, and is a valuable and highly nutritive substance, apt, however, to have a rather bitter taste.

Plantose is a very similar vegetable protein obtained from rape seed. Roborat and Glidine have been described already (p. 220).

2. Digested Protein Foods, or 'Peptone Preparations.'—Before describing the members of this group in detail, one or two preliminary questions must be considered. And first it may be asked, Are peptones of as much value in the diet as proteins? Are they equally well assimilated and as capable of repairing tissue waste? At one time some doubt existed about these questions, but now one may say with confidence that peptones are fully capable of playing the part in nutrition ordinarily taken by proteins, provided they be given by the mouth.¹ If injected directly into the circulation, it is true that they are not assimilated, but if taken in the ordinary way they are converted into natural proteins before entering the blood.

It has also been objected that the substitution of peptones for ordinary proteins in the diet must tend to demoralize the stomach by doing some of its work for it, and so render it incapable, through want of practice, of performing its usual digestive functions. This objection seems to be a hypothetical rather than a practical one, and with the exception of one experiment by Roberts,² on which he did not himself lay much weight, there is little evidence in support of it. Further, it must be remembered that peptones are not intended for the healthy, but for those in whom the stomach is presumably already incapable of doing its work, and in such a case the administration of peptones, by improving general nutrition, might be expected to strengthen rather than to enfeeble the digestive powers.

A much more real disadvantage attending the use of peptone

¹ See especially Hildebrandt, *Zeit. f. Physiolog. Chem.*, 1893, xviii. 180; Neumeister, *Deut. Med. Woch.*, 1893, xix. 866, and Von Noorden, *Therap. Monatsheft*, 1892, vi. 271.

² 'Digestion and Diet,' p. 209.

preparations is their tendency to produce diarrhœa, for when introduced suddenly and in large amounts into the stomach and intestine, they seem to induce a large flow of water into the alimentary canal from the blood, and this is accompanied by an increased activity of peristalsis. For this reason they must always be used cautiously and in moderate quantity, while in conditions of diarrhœa the more concentrated forms should be avoided altogether.

It may be questioned, too, whether the cases in which peptones are really required are at all numerous, for an inability on the part of the stomach to digest ordinary proteins properly presented to it, and in a state of fine division, must be regarded as of very rare occurrence. On the other hand, peptone preparations appear to have the power of exciting a secretion of gastric juice, and of promoting appetite in much the same way as the extractives of meat. Their nutritive value, therefore, is indirect rather than direct, and is to be measured more by their general effect upon the well-being of the patient than by the amount of energy which they supply.¹

Of solid peptone preparations **Somatose**² is the best example. Strictly speaking, it consists of albumoses rather than of genuine peptone, but the same is true of the majority of the so-called peptone preparations, and for dietetic purposes albumoses and peptones may be regarded as identical. Somatose is prepared from meat, and occurs as a grayish powder, readily soluble in water and practically devoid of taste or odour. The following is an analysis of it by Tankard:³

Water	14·25 per cent
Alkali albumin	21·83 ..
Coagulable albumin	3·40 ..
Albumoses	33·96 ..
Peptones	3·06 ..
Meat bases	2·62 ..
Ash	5·30 ..

¹ See a paper by F. Voit, 'Ueber den Werth der Albumosen und Peptone für die Ernährung' (*Münch. Med. Wochensch.*, 1899, xli. 172); also Max Voit, *Zeit. f. Biologie*, 1903, xlv., N.F., xxvii. 79.

² Somatose is not at present obtainable in this country.

³ Allen's 'Commercial Organic Analysis,' iv. 384.

Roughly speaking, it may be said to contain from 60 to 70 per cent. of building material, and a teaspoonful of it is equal in this respect to about $\frac{1}{2}$ ounce of lean meat. It can be easily added to fluid or semi-fluid foods, but if largely used may produce diarrhoea.¹ The dose recommended is about three or four teaspoonfuls daily, and it seems to be very well absorbed.² Like most of the preparations we are now considering, Somatose is rather expensive, an ounce of it costing 1s. 8d., and yielding for that sum only as much nutriment as $\frac{1}{4}$ pound of beef.

Carnrick's Peptonoids is another solid preparation containing predigested proteins. The following is Tankard's analysis of it:³

Water	2.13 per cent.
Insoluble proteins	12.22 ..
Albumoses	3.17 ..
Peptones	0.88 ..
Meat bases	2.87 ..
Starch	23.64 ..
Milk-sugar	48.52 ..
Fat	2.00 ..
Ash	4.57 ..

It will be observed that the substance owes its nutritive value to carbohydrates rather than to proteins, and that the larger part of the latter is present in an insoluble form.

The tables on p. 559 contain analyses of some of the semi-solid and liquid peptone preparations.

¹ See Bornstein, *Berlin. Klin. Woch.*, No. 8, 1897.

² For literature relating to Somatose and its uses, see Hildebrandt, *Verhand. d. 12ten Cong. f. Inn. Med.*, 1893, 395; also references in *Edin. Med. Journ.*, February, 1899, and the *British Physician*, July 15, 1899; also a paper by Stevenson and Luff, *Lancet*, September 30, 1899. The conclusions of the two latter writers are as follows:

- i. Somatose is a true meat nutrient possessing restorative and stimulating powers.
- ii. It is well borne by delicate patients.
- iii. It improves digestion and causes no gastro-intestinal disturbances.
- iv. It has a favourable effect on general metabolism.
- v. It never gives rise to the appearance of albumin, albumose, or peptone in the urine.

³ Allen, *loc. cit.*

COMPOSITION OF PEPTONE PREPARATIONS (CHIEFLY FROM ANALYSES BY THE AUTHOR).

Preparation.	Water.	Soluble Proteins (chiefly Albumoses).	Extractives and other Non protein Organic Matter.	Mineral Matter.
Koch's Peptone	40·16	34·78	15·93	6·89
Liebig's Peptone ¹	31·9	33·40	24·6	9·9
Brand's Beef Peptone	84·6	7·0	—	1·4
Denaeyer's Peptone ¹	78·45	12·15	4·32	2·54
Darby's Fluid Meat ²	25·71	30·60	30·18	13·50
Armour's Wine of Peptone	83·0	3·0	12·9	1·1
Fairchild's Panopepton	81·0	3·0	15·0	1·0
Peptonized Milk ⁴	87·5	1·76	(largely sugar) 10·04 (= sugar, fat, and unaltered proteid)	0·7

¹ Leyden's 'Handbuch der Ernährungstherapie.'² *Ibid.*; see also Von Noorden, *Therap. Monatsheft*, June, 1892.³ Horton Smith, *Journ. of Physiolog.*, xii. 42, 1891, and Leyden's 'Handbuch.'⁴ Horton Smith, *loc. cit.*

COMPOSITION OF SOME PEPTONE PREPARATIONS (KÖNIG).

Preparation.	Water.	Total Nitrogen.	In-soluble Protein.	Albumoses.	Pep-tones.	Other Nitro-genous Com-pounds.	Fat.	Ash.
Antweiler's Peptone	6·92	12·85	3·22	14·54	60·15	1·20	0·54	13·31
Kemmerich's Meat Pep-tone (dry) ..	33·30	9·78	1·10	14·56	32·57	9·97	0·30	7·73
Koch's Meat Peptone (dry)	40·16	7·80	1·42	15·95	18·83	15·96	0·79	6·89
Darby's Fluid Meat ..	25·71	3·06	—	—	30·60	—	—	13·50
Valentine's Meat-juice ..	59·07	2·50	—	1·81	4·87	22·73	—	11·52
Savory and Moore's Fluid Beef	27·01	8·77	—	5·42	2·74	52·73	—	12·10
Benger's Pep-tonized Beef Jelly ..	89·68	1·55	—	2·41	4·75	2·27	—	0·89

Most of these contain so much water that their nutritive value is comparatively small, while those in which alcohol is present are open to the same objections as other dietetic or medicinal wines¹ (see p. 388).

¹ Analyses by Harrington (*Boston Med. and Surg. Journ.*, 1902, clxviii. 283) have shown for example that 'liquid peptonoids' contain 23 per cent. of alcohol by volume, and that the maximum dose for an adult per day would yield as much intoxicant as is contained in 3½ ounces of whisky. 'Panopepton' contains 18·95 per cent. of alcohol by volume.

Home-made peptonized foods, prepared by aid of such agents as liquor pancreaticus or 'zymine,' are now so well known and widely employed that a special description of them is unnecessary.¹ Peptonized milk is that most commonly used. An analysis of it will be found in the foregoing table. Condensed peptonized milk is sold in tins by Messrs. Savory and Moore.

Gruels of various sorts can be prepared in a similar way, peptonized milk gruel being one of the best. Such home-made preparations are mostly to be preferred to commercial articles, and have also the advantage of being very much cheaper.

ARTIFICIAL CARBOHYDRATE FOODS

Many patent foods which might justly be included in this section have been already dealt with under the cereals, pulses, etc. The only group which remains to be considered is that of the **malt-extracts**. These are prepared by evaporating down an infusion of malted barley at low temperatures or *in vacuo*. The object of evaporating them in that way is to preserve in an active form the diastasic ferment present in the malt; and the special apparatus required for this purpose is one cause of the expense of such preparations.

The following table contains the results of the analyses of some standard malt-extracts:²

COMPOSITION OF MALT-EXTRACTS.

	Total Solids.	Reducing Sugars. ³	Protein.	Dextrin.	Ash.	Alcohol.	Diastasic Power.
Kepler Extract of Malt ..	78.4	67.7	5.66	7.4	1.5	—	380
Trommer's Extract of Malt	73.6	55.9	4.05	8.3	1.1	—	23
Allen and Hanbury's Extract of Malt ..	79.0	65.2	4.55	13.4	1.2	—	39
D.C.L. Malt-Extract ..	78.3	70.9	6.25	10.0	1.4	—	366
Cream of Malt ..	73.8	60.8	5.55	13.8	1.8	—	86
Maltine ..	67.3	61.9	5.25	5.0	1.2	—	940
Standard Malt-Extract ..	76.6	70.0	5.3	12.2	1.4	—	382
Bynin ..	52.9	51.6	3.3	3.1	0.9	8.3	38
Standard Liquid Malt-Extract ..	53.7	51.6	5.5	2.3	1.1	5.0	866
Hoff's Malt-Extract ..	7.8	2.5	0.4	2.3	0.2	3.1	0

The average composition of these substances given by Klemperer⁴ is as follows:

Sugar 50 to 55 per cent.	Proteins 5 to 6 per cent.
Soluble starch.. 10 „ 15 „	Ash 1 „ 2 „

¹ For details, see Roberts' 'Digestion and Diet,' 2nd edit., p. 192. Full directions for preparing peptonized foods are supplied along with the agents mentioned in the text.

² *Brit. Med. Journ.*, 1909, ii. 1477.

³ Calculated as maltose.

⁴ Leyden's 'Handbuch der Ernährungstherapie.'

A large dessertspoonful of such an extract weighs about 20 grms. and has a fuel value of 60 Calories, or about as much as an egg.

In the above analyses the whole of the nitrogenous matter has been counted as protein, but it is very doubtful if that is quite accurate. Some of the nitrogen is almost certainly present in other forms.

Desiccated malt extracts¹ from which all the water has been removed are also prepared. They are of high nutritive value and active diastasic power, and are in many respects more convenient than the ordinary extracts. Hoff's Malt Extract, on the other hand, is a liquid preparation. **Maltova** is a combination of malt-extract and eggs.

Malt-extracts may be prescribed with one of two objects: (1) To enrich the supply of carbohydrates in the diet; (2) to aid the digestion of starchy foods by means of the diastase which the extract contains. The advantages possessed by malt-extracts for accomplishing the former of these objects are not quite apparent. **Treacle and golden syrup** both contain a considerably higher percentage of sugar, and are vastly cheaper. It is true that malt-sugar is less apt to irritate the stomach than the cane-sugar which treacle and syrup contain; and although not capable of direct absorption as such, maltose may yet be regarded as a partially digested form of carbohydrate. But in both these respects we have in ordinary honey a superior food.

Honey has the following composition:

Water	..	..	..	..	16 to 13 per cent.
Invert sugar	..	..	..	..	78 „ 74 „
Cane-sugar	..	..	..	..	2'69 „
Proteid	..	..	..	..	1'29 „
Ash ..	..	..	..	..	0'12 „

That is to say, it is actually richer in sugar than malt-extract; and a dessertspoonful has a fuel value of 75 instead of 60 Calories. Furthermore, the sugar of honey is really in a predigested form, and ready for immediate assimilation. As a source of carbohydrate, therefore, honey is in every way preferable to malt-extracts, besides being a good deal cheaper;² and it may be used with great advantage in every case in which one wishes to supplement the supply of carbohydrates in the diet.

The second property of malt-extracts—that of acting upon starch by means of the diastase which they contain—is but rarely present

¹ *E.g.*, Curtis' Desiccated Malt-Extract (Curtis and Co., 48, Baker Street, W.); 'Gramalt' (Thomas Christy and Co., Old Swan Lane, Upper Thames Street, E.C.), and Dr. Wander's Dry (Crystalline) Extract of Malt. For results obtained from the use of desiccated malt-extract see 'Powdered Malt-Extract as a Nutrient,' by Dr. Hingston Fox (*Brit. Med. Journ.*, 1902, i. 835).

² Malt-extracts cost about 3s. the pound, honey costs about 9d.

to the mind of the prescriber. The cases in which such an action is desired are not, indeed, at all numerous, and are practically confined to the group of so-called amylaceous dyspepsias. Even in such a case malt-extract is not the best preparation to employ. No matter how carefully the extract may be prepared, it always seems to lose something of its diastasic power in the process (Roberts); and it is far more certain, as well as cheaper, and one may add pleasanter, to make an infusion of malt at home, and either use it as a beverage at meals, or, preferably, stir it into starchy foods, such as puddings or gruel, before they are eaten.¹

The value of *milk-sugar* as a means of supplementing the carbohydrates of the diet must not be forgotten. Its comparative freedom from sweetness makes it specially suitable for such a purpose. If $\frac{1}{2}$ ounce of it is dissolved in 5 or 6 ounces of milk, the nutritive value of the latter is increased by nearly 60 Calories. This may often be taken advantage of in feeding patients with acute fevers.

ARTIFICIAL FATTY FOODS.

In most cases these consist of some kind of fat presented in the form of an emulsion, cod-liver oil being the special variety of fat usually employed.

The object of emulsification is to render the fat more palatable, and also to aid its digestion. The former object is undoubtedly attained; the achievement of the latter is not so certain. It must be remembered that what is now known of the digestion and absorption of fat makes it certain that the process is mainly a chemical one, and not a mere physical absorption of the fat in the form of fine particles. Hence, though emulsification may be a useful preliminary to digestion, fat so presented cannot be regarded as ready for immediate reception into the blood. Like the malt-extracts, therefore, fat emulsions are only partially predigested foods.

The emulsifying agent in these preparations is either an alkaline solution, mucilage, glycerine, or malt-extract. Of these, the three last are to be preferred, for they are unaffected by the acidity of the gastric juice, which is apt to destroy an alkaline emulsion.

An ordinary cod-liver oil emulsion contains about half its weight of fat, and has a fuel value about double that of an equal quantity of malt-extract. The question whether cod-liver oil has any specific

¹ Roberts recommends an infusion made by soaking 3 piled tablespoonfuls of crushed malt in $\frac{1}{2}$ pint of cold water overnight, and straining through muslin till clear. It may be preserved in a tightly-corked bottle with the addition of a few drops of chloroform ('Digestion and Diet,' p. 230, where detailed directions for the use of such an infusion are given)

virtues other than those of an easily-digested fat cannot be discussed here; but in the case of the purified oils, at any rate, any such specific qualities can hardly be present, unless they be due to cholesterol, the food value of which, however, is very questionable.

A preparation called **Liparin** has been largely used in Germany as a substitute for cod-liver oil. It consists of ordinary olive oil containing 6 per cent. of oleic acid. The presence of the latter is supposed to facilitate emulsification and absorption in the intestine; but experiment has not shown that Liparin is better absorbed than ordinary forms of fat.¹ The composition of some standard emulsions of cod-liver oil and malt is as follows:²

Preparation.	Protein.	Reducing Sugars calculated as Maltose.	Fat.	Diastatic Power.
Bynol	4·6	52·2	12·9	22
Trommer's Oil and Malt ..	2·4	41·4	29·9	35
'Maltine' and Cod-Liver Oil ..	3·8	41·4	22·7	284
Kepler's Oil and Malt	3·4	42·5	17·4	3
'Diamalt' with Cod-Liver Oil	5·1	51·0	16·6	592

Miol is a combination of emulsified olive oil with malt-extract, and contains, in addition, iodine, phosphorus, and other ingredients. It is designed to replace cod-liver oil, and contains 22 per cent. of fat and 41 per cent. of reducing sugar.

Virol is another cod-liver oil substitute. It is prepared from bone marrow, the yolk of eggs, and malt-extract flavoured with lemon-juice, and has approximately the following composition:

Water	21·1 per cent.	Protein	2·8 per cent.
Fat	12·3 ..	Ash.. .. .	1·6 ..
Carbohydrates ..	59·0 ..		

It is an agreeable preparation of very considerable nutritive value.

Cremalto is a combination of Devonshire cream and malt which has the following composition:³

Water	26·7 per cent.	Protein	4·1 per cent.
Fat	11·7 ..	Ash.. .. .	1·3 ..
Carbohydrates ..	56·3 ..		

It also is a pleasant and nourishing preparation.

Pancreatic Emulsion is another substitute for cod-liver oil. It is made by pounding up lard with pig's pancreas, with the addition of water, straining, and exhausting the strained substance with ether. The ether is distilled off, and the residue of fat is mixed with rectified

¹ See Leyden's 'Handbuch der Ernährungstherapie,' p. 302.

² *Brit. Med. Journ.*, January 1, 1910.

³ Analysis in *Brit. Med. Journ.*, 1910, i. 29.

spirit and water, and emulsified by agitation. Oil of cloves is added to give flavour and aid preservation.

It is not difficult to take, but is no richer in fat than ordinary butter, and considerably more expensive.

Spermaceti used to be largely employed as a means of giving fat, but has now dropped out of use. It was given in the form of a powder mixed with sugar, and $\frac{3}{4}$ ounce could be taken daily.¹ It is well borne and not difficult to absorb.

The objection to all these artificial preparations is their expense, and for that reason, if for none other, the use of natural fats is preferable. Of these, cream and butter are the most suitable, for there are but few persons who are unable to digest milk-fat. Ordinary cream, obtained by skimming, contains about 20 per cent. of fat, and three spoonfuls of it are more than equal in fuel value to one spoonful of cod-liver oil emulsion. **Butter** has 80 per cent. of fat, and can be taken in large quantities if well mixed with starchy foods such as mashed potato. **Almonds** are also a rich source of fat, of which they contain more than half their weight. **Chocolate**, too, has 20 per cent. of fat and 50 per cent. of sugar in addition. Lastly, one should not forget the value of **toffee** as a concentrated form of fat and carbohydrate in about equal proportion. It has the further advantage that much of the sugar which it contains is in the easily digested 'invert' form. It may be specially recommended in the case of children who are unable to take cod-liver oil or other forms of fat, and if given only at the end of meals is not likely to do any harm. If the merits of some of these natural forms of fat were rightly appreciated, there would be but little need to have recourse to artificial preparations.

2. Artificial Feeding.²

RECTAL FEEDING AND NUTRIENT ENEMATA.

Rectal feeding has constituted a therapeutic resource ever since medical science existed,³ but it is only within recent times that the value of this method of administering nourishment has been subjected to careful scientific scrutiny.

¹ See Senator, *Berlin. Klin. Woch.*, 1887, xxiv. 213.

² For a critical review of the whole subject of artificial feeding, see an article entitled 'Extrabuccal Feeding,' by C. A. Ewald, *Med. Record*, 1900, lviii. 241.

³ For a sketch of the history of the subject, see the valuable monograph by Dr. A. P. Gros, 'Traitement de certaines Maladies de l'Estomac par la Cure de Repos absolu,' etc.; Paris, 1898.

The absorptive power of the large intestine for **proteins** was first investigated by Eichhorst,¹ Leube,² Brandenburg,³ Huber,⁴ Ewald,⁵ Plantenga,⁶ and others. Their results showed that: (1) Peptone is well absorbed; (2) eggs given alone are not well absorbed, but if 15 grains of salt are added to each egg they are almost as well utilized as if they had been peptonized; (3) raw-beef juice is very completely absorbed; (4) albuminoids such as gelatin are not absorbed.

Results obtained with enemata of casein were conflicting. Some of the above observers state that it is not well absorbed, but Eichhorst, and more recently Ehrström⁷ (who used a soluble casein preparation) maintain that it is well taken up by the rectal mucous membrane. Hoppe⁸ also found that Sanatogen is absorbed to the extent of fully 77 per cent., and Golinier⁹ that Plasmon dissolved in hot water makes a satisfactory enema.

Later observations tend to throw much doubt upon the trustworthiness of these earlier experiments upon the absorption of proteins from nutrient enemata. Rendle Short and Bywaters,¹⁰ for instance, who have reinvestigated the whole subject, come to these conclusions:

1. The older observations on the absorption of foodstuffs from rectal enemata, based on the analysis of rectal 'wash-outs,' are unreliable.

2. The daily output of nitrogen in the urine of patients given nutrient enemata of milk or eggs peptonized for twenty or thirty minutes demonstrates that almost no nitrogenous matter is absorbed.

3. Modern physiological opinion holds that proteins are absorbed principally as amino-acids. The failure of the rectum to absorb ordinary nutrient enemata is largely due to the fact that peptones are given instead of amino-acids.

4. Chemically prepared amino-acids, or milk pancreatized for twenty-four hours so that amino-acids are separated, allows of a much better absorption of nitrogenous foodstuffs from the rectum, as demonstrated in five cases by the high nitrogen output in the urine.

¹ *Archiv. f. Physiolog.*, 1871, iv. 570.

² Leyden's 'Handbuch der Ernährungstherapie,' p. 496 *et seq.*

³ *Deut. Archiv. f. Klin. Med.*, 1896, lviii. 71.

⁴ *Ibid.*, 1891, xlvii. 495.

⁵ *Archiv. f. Anat. und Physiolog.*, 1899, Supp. Bd., p. 160.

⁶ *Centralbl. f. Physiolog.*, 1899, xii. 734, (abstract of dissertation); see also Gros, *op. cit.*

⁷ 'Ueber den Nährwerth der Casein Klystiere,' *Zeit. f. Klin. Med.*, 1903, xlix. 377.

⁸ *Munch. Med. Wochens.*, 1904, li. 2294.

⁹ *Zeit. f. Phys. und Diät. Therapie*, February, 1907.

¹⁰ 'Amino-Acids and Sugars in Rectal Feeding,' *Brit. Med. Journ.*, 1913, i. 1361.

5. The low output of ammonia nitrogen shows that this high output was not due to the absorption of putrefactive bodies. The rectal washings were not offensive.

As regards **carbohydrates**, it has been found that sugars are well absorbed, but are apt in concentrated solution to prove irritating to the mucous membrane. Leube advises that the solution should not be stronger than 10 to 20 per cent., and that not more than 300 c.c. should be given at one time. Even then there is a risk of the enema being very soon returned. A 6 per cent. solution of dextrose in tap-water, which is isotonic with blood, is much less irritating.¹ Curiously enough, starch seems to be fairly well absorbed,² even when given in the raw state: 50 to 100 grammes of it may be given in 300 c.c. of water. It is not at all irritating.

Fats are not at all well absorbed when given by the bowel.³ The total amount absorbed depends on: (1) The absolute quantity administered; (2) its length of stay in the bowel; (3) the temperature of the enema and the presence or absence in it of common salt. Not more than 25 grammes of fat should be given at once, and with at least as much water. The enema should be given at the body temperature, and enough salt added to form a normal saline solution. The bowel should be empty, and only one enema given daily. Even under these favourable conditions, not more than 10 grammes of fat are likely to be absorbed daily. Scarcely any of the fat of ordinary milk enemata appears to be retained.

It follows from these experimental results that the best ingredients for nutrient enemata are: (1) Peptones, albumoses, and powdered casein preparations; (2) eggs, with the addition of salt; (3) raw-beef juice; (4) dilute solutions of grape-sugar or dextrin; (5) and perhaps unboiled starch. To this list should be added alcohol, which is perhaps better absorbed by the large intestine than anything else except water.⁴

¹ Mutch and Ryffel, *Brit. Med. Journ.*, 1913, i. 111.

² This statement is not quite borne out by the observations of Reach ('Ueber Resorption von Kohlehydraten von der Schleimhaut des Rektums,' *Zeit. f. Diät. und Physik. Therapie*, 1903, vii. 229). He administered enemata of 60 grammes of sugar or dextrin in 120 to 200 c.c. of water, and of 100 grammes of starch in 300 c.c. of water, using the respiratory quotient as the test of absorption. He concludes that some sugar is absorbed, but very little starch. He is inclined to recommend the use of dextrin, for it is as well absorbed as sugar, and less irritating to the mucous membrane. O. Leyton has found that 30 grammes of sugar can be absorbed without the production of glycosuria. Fallerman (*Quart. Journ. of Med.*, 1920, 13, p. 356) showed by observations of the blood sugar in patients that glucose is absorbed from the rectum, the maximum rise being reached in about one hour twenty minutes.

³ See Deucher, *Deut. Archiv. f. Klin. Med.*, 1897, lviii. 210.

⁴ The whole subject of rectal alimentation was reviewed by Sharkey in the Bradshaw Lecture, 1906 (*Lancet*, 1906, ii. 1263), but his conclusions are in the main in agreement with those expressed in the above paragraph. He gives a very complete bibliography of the subject.

It may be admitted that the capacity of the large intestine to absorb some of these articles is not easy of explanation. It is pretty clearly established that the colon secretes no digestive ferments. How, then, it may be asked, is it capable of absorbing such substances as egg-white and unboiled starch? There is one easy way out of the difficulty, and that is by assuming the occurrence of a **reverse peristalsis**, which carries substances injected into the rectum up above the ileo-cæcal valve into the small intestine. That such a reverse peristalsis is possible is, I think, no longer open to doubt. It is proved by the experiments of Grützner,¹ by the observations of Nencki, Macfadyen and Sieber on a patient with a fistula at the lower end of the ileum,² and by the incontestable fact of the occasional vomiting of enemata by hysterical patients.³

It is very probable that in this way a part at least of a nutrient enema gets carried into the small intestine, where absorption can readily occur. Variations in the patency of the ileo-cæcal valve may explain the different degrees to which different individuals absorb such enemata.

Special emphasis must be given to the great extent to which the **addition of salt to nutrient enemata** promotes their absorption. This is a practical matter of the first importance. Its *modus operandi*, however, is not easy of explanation. It may perhaps stimulate the appearance of the reverse peristalsis above referred to, or it may excite the intestinal cells to greater absorptive efforts, while it undoubtedly facilitates the diffusion of the enema over the surface of the bowel.

Putting aside these rather academical discussions, there is abundant clinical evidence for the feasibility of nourishing patients, for some time at least, by the rectum exclusively. In several cases cited by Gros, patients were fed by this method alone for as long a period as three weeks, and with but little loss of weight.⁴

The process, however, cannot be continued indefinitely, for, apart altogether from the fact that the rectum sooner or later becomes intolerant, one can hardly hope, allowing for deficient absorption, to get more than 500 Calories of energy into the blood daily by this means, and that is only about a quarter or at most one-third of the amount required even by patients who are kept very warm and at absolute rest. Much of the value of nutrient enemata, indeed, is

¹ *Pflüger's Archiv.*, 1898, lxxi. 492.

² *Archiv. f. Exper. Path. und Pharmacol.*, 1891, xxviii. 311.

³ Gros, *op. cit.*, chap. iv.

⁴ See also Ewald, *Archiv. f. Anat. und Physiolog.*, 1899, Supp. Bd., 160, and Rost, *Berlin. Klin. Woch.*, 1899, xxxvi. 660, 686.

almost certainly due to absorption of water, which may explain the cases in which weight is gained. It is only in exceptional cases that one can prevent tissue-loss by their use, and the best that can be hoped for is to prevent the patient losing ground when already in a condition of decided sub-nutrition.¹ It has been proved, also, that the administration of a nutritive enema is followed by the out-pouring of some gastric juice into the stomach, and in cases of gastric ulcer this may be harmful and interfere with healing.

Milk is most commonly used as the basis for enemata, as it is simple, convenient and unirritating, in spite of the fact that only about one-third of the casein which it contains is absorbed. The following are some of the formulæ for enemata containing milk recommended by Leube:²

Peptone and Milk Enema.

Peptone, 60 grammes.
Milk, 250 c.c.

Egg and Milk Enema.

3 eggs.
3 grammes of common salt.
Milk, 250 c.c.

Sugar and Milk Enema.

Grape-sugar, 60 grammes.³
Milk, 250 c.c.

Starch and Milk Enema.

Starch (unboiled⁴). 60 to 70 grammes.
Milk, 270 c.c.

It might be well to peptonize the milk first. Somatose may be used instead of peptone.

Red wine is recommended as an addition by many Continental writers. The alcohol which it contains is readily absorbed, while its astringency and slight acidity seem to favour retention of the enema.⁵ The following formulæ are examples :

Ewald's Enema.

2 tablespoonfuls of wheat flour.
5 ounces of lukewarm water or milk.
1 or 2 eggs with a pinch of salt.
Beat up with 2 to 4 ounces of a 15 per cent. solution of glucose.
Then add 1 glass of claret.

¹ See Edsall and Miller, *Univ. of Pennsylv. Med. Bull.*, January, 1903, xv. 414 (abstract in *Brit. Med. Journ.*, Epit., 1903, 83).

² 28 grammes, or 28 c.c. = 1 ounce.

³ This would be contained in about 3 ounces of honey.

⁴ Boiled starch is too thick to inject.

⁵ Bial (*Arch. f. Verdauungs.*, 1903, ix. 433) found that of an enema containing 10 per cent. of peptone 50 per cent. was absorbed, but that by the addition of 10 per cent. alcohol the absorption was raised to 66 per cent.

Boas' Enema.

Milk, 9 oz.
 Yolks of 2 eggs.
 A pinch of salt.
 Red wine, $\frac{1}{2}$ oz.
 Starch or arrowroot, $\frac{1}{2}$ oz.

Riegel's Enema.

Milk, 9 oz.
 2 to 3 eggs.
 2 to 3 pinches of salt.
 Red wine, 1 oz.

Tournier's Enema.

Beef-tea,¹ 5 ozs.
 The yolks of 6 eggs.
 2 small spoonfuls of salt.
 Red wine, 1 oz.

The eggs should be beaten up for at least five minutes, so as to mix them thoroughly.

Boyd and Robertson² find that for practical purposes the following is the best formula to use :

The yolks of two eggs
 30 grammes pure dextrose,
 0.5 gramme common salt.
 Pancreatized milk to 300 c.c

Given every six hours the amount of nourishment injected would equal 1,200 Calories. Absorption under favourable circumstances might amount to 500 Calories, but would probably be much less.

Leube's Pancreas Enema is an attempt to imitate natural intestinal digestion. It consists of a mixture of chopped pancreas and lean meat, with the addition of some fat, in the following proportions :

Pancreas	..	..	..	..	50 to 100 grammes.
Meat	..	..	..	..	150 ,, 300 ,,
Fat..	..	..	..	..	30 ,, 45 ,,

The pancreas and meat should both be free from fat, and chopped as finely as possible. They are stirred up in a basin with a large spoon, 150 c.c. of lukewarm water being added. The fat should be mixed with the mass in a mortar very thoroughly by aid of a warm pestle.

Leube claims that this enema is unirritating and well retained, and that the fat in it is freely absorbed and can be demonstrated in the cells of the large intestine in the form of droplets. No starch should be added, for sugar is produced from it so rapidly that it irritates the mucous membrane of the bowel. Others, however,

¹ Raw-beef juice would be better.

² *The Scottish Med. and Surg. Journ.*, March, 1906, xviii. 193.

have found that this enema results in a great deal of intestinal putrefaction, and even in some degree of toxæmia.¹

O. Grünbaum² has used enemata of ox-serum³ with success, 2 grains of chloretone being added to each ounce of the serum to act both as a sedative and a preservative. Ninety c.c. ($3\frac{1}{4}$ ounces) may be injected every four hours, which yields 38 grammes of protein in the day. By the addition of 60 c.c. (about 2 ounces) of milk the total protein is raised to 51 grammes per day. He has found that such enemata are very well absorbed.

Rendle Short and Bywaters⁴ are of opinion that the best nutrient enema is one composed of milk pancreatized for twenty-four hours, with the addition of 5 per cent. of dextrose. Goodall⁵ uses a mixture of 50 grammes each of dextrose and alcohol in 1,000 c.c. of water. An enema of this volume is completely absorbed in eight hours, and yields 555 Calories. Mutch and Ryffel⁶ recommend simply a 5 per cent. solution of dextrose in tap-water, and give 15 ounces of this four times a day.

Recent opinion is all in favour of using these simpler enemata in place of the older mixtures containing proteins and fat. They appear to effect all that can be achieved by rectal feeding without the trouble and uncleanliness of the more elaborate formulæ.

GENERAL TECHNIQUE.

Enemata should be given at the body temperature, and their bulk should not exceed 250 c.c. (about 9 ounces). Fluids should be given through a soft œsophageal tube of small calibre, introduced as high as possible, and connected with a funnel raised to a height of 3 feet. Thicker mixtures (such as the pancreas enema) should be administered by means of an ordinary enema or pressure syringe. The enema should be given slowly, and the patient should lie quiet for an hour after it has been injected. Three or four enemata in the twenty-four hours is a sufficient quantity, and one cleansing injection should be given daily, for absorption is greatly promoted by having the surface of the mucous membrane clean. If the enema is badly retained, a little opium may be added.

Nutrient suppositories cannot be recommended. They usually contain peptone, but at most not more than 125 grains in each,

¹ See Boyd and Robertson, *loc. cit.*

² *Brit. Med. Journ.*, 1900, ii. 424, and 1901, xi. 788.

³ Supplied by Parke, Davis and Co.

⁴ *Loc. cit.*

⁵ 'Rectal Alimentation,' *Boston Med. and Surg. Journ.*, January, 1914, p. 41.

⁶ *Loc. cit.*

which means, even assuming complete absorption, an energy value of less than 35 Calories. The absorption of such suppositories has been found in some cases to be very far from perfect.¹

SUBCUTANEOUS FEEDING.

The injection of nutritive substances under the skin may be regarded as the latest method of administering food artificially. It was first introduced by Menzel and Perco in the year 1869,² but has only come into use very slowly since that date.

In order that a food may be available for subcutaneous administration, it must fulfil three conditions :

1. It must be capable of direct assimilation.
2. It must be unirritating.
3. It must be of such a nature that it can be easily sterilized.

There are but few foods which meet all these requirements.

Most proteins are unsuitable, because those which can be directly assimilated by the tissues are not easily sterilized without undergoing coagulation; and, on the other hand, those which can be readily sterilized, *e.g.*, peptones and albumoses, are not directly appropriated by the tissues, and even act as poisons to them.³

A solution of egg white, even supposing it to be assimilated, which some writers deny, is difficult to prepare in a sterile form, and is apparently apt to cause damage to the kidneys.⁴

Serum, however, contains proteins in a form in which they can be sterilized without much difficulty, and which are directly assimilable. If serum is heated to 55° C., it becomes opalescent, but does not coagulate, and can then be injected without danger.⁵

Reinach⁶ brought round children who were very much exhausted by diarrhoea by injecting 20 c.c. of ox serum under the skin at the sides of the thorax. This quantity, however, contains only about 1½ grammes of protein, and it is probable that the injection of salt solution would have an equally favourable effect.

¹ Boas, however, puts in a claim for the restricted utility of nutrient suppositories in a few cases ('Über Nahrungsuppositorien,' *Berlin. Klin. Woch.*, April 4, 1910).

² For the history of subcutaneous feeding, see Bauer, 'The Dietary of the Sick' (Von Ziemssen's 'Handbook of General Therapeutics,' vol. i.), p. 271, and Leube in Leyden's 'Handbuch der Ernährungstherapie,' i. 513.

³ See Neumeister, *Deut. Med. Woch.*, 1893, xix. 866.

⁴ See Leigh ('Nutritive Infusions') *New York Med. Journ.*, 1902, lxxvi. 368; Jackson ('Subcutaneous Injections of White of Egg'), *ibid.*, 1902, lxxvi. 813; and Laborde ('De l'Alimentation Sous-cutanée par les Matières Albuminoïdes'), *J. de Physiol. et de Pathol.*, 1900, ii. 700.

⁵ Friedenthal and Lewandowsky, *Archiv. f. Anat. und Physiolog.*, 1899, 531.

⁶ *Berlin. Klin. Woch.*, March 20, 1899.

Horse serum contains from $7\frac{1}{2}$ to 8 per cent. of protein,¹ and is a more suitable form for administration in this way. Salter² has injected as much as 100 to 120 c.c., previously heated to 65° C., of it under the skin in adults without any bad effects. No albuminuria appeared, and the total nitrogen excretion in the urine was increased. The total amount of protein which can be administered by this method, however, can never be of much nutritive importance.

Carbohydrates in the form of grape-sugar are easily sterilized, and can be directly assimilated. F. Voit³ found that as much as 60 grammes of grape-sugar in 10 per cent. solution could be injected under the skin of the thigh without glycosuria resulting. Unfortunately, however, sugar solutions are irritating, and much pain and infiltration are apt to be produced at the site of injection. Müller,⁴ for instance, injected a 10 per cent. solution under the skin of his own thigh, but so much pain was produced that he resolved never to try the experiment again. Leube⁵ states that at most 15 to 20 grammes of grape-sugar can be injected without great pain resulting. Barker⁶ recommends the injection of a 5 per cent. solution of glucose in normal saline in conditions of exhaustion or collapse before or after operation. A litre of such a solution may be given in the day, 500 c.c. being injected at a time. The injection is made under the skin near the axilla through an ordinary aspirating needle connected with a funnel by 3 feet of rubber tubing. A similar solution may also be used intravenously.⁷

Fat, in the form of oil, is really the only form of food which fulfils all three conditions, and accordingly it is the only food substance which can be injected under the skin with any freedom. The dangers of producing fat embolism would seem to be imaginary. Leube, after a very considerable experience, has never seen it occur.

Olive and sesame oils are the best forms to use: 30 to 40 c.c. should be injected with a 10 c.c. syringe at three different places, the injection being performed slowly and without much pressure, and the puncture sealed with collodion. Injection should be performed only once a day, and the groin is perhaps the best site to select.

That oil so injected is really assimilated is evidenced by the fact

¹ Szontagh and Wellmann, *Deut. Med. Woch.*, 1898, xxiv. 421.

² *Guy's Hospital Reports*, 1896, liii. 241.

³ *Münch. Med. Woch.*, 1896, xliii. 717, and 1897, xlv. 851.

⁴ Gumprecht, *Verhand. d. Cong. f. Inn. Med.*, 1898, xvi. 124.

⁵ *Verhand. d. Cong. f. Inn. Med.*, 1895, xiii. 418.

⁶ *Brit. Med. Journ.*, 1902, i. 770.

⁷ Kausch, 'Über intravenöse und subkutane Ernährung mit Traubenzucker,' *Deut. Med. Woch.*, January 5, 1911.

that the excretion of nitrogen is lessened by it,¹ and post-mortem also the fat is found to have disappeared from the point of injection. If the oil be properly sterilized, no local irritation is ever produced, and the injections may be continued for as long as four weeks without bad results.²

Caird³ reports a case of stricture of the œsophagus in which the patient was going downhill under enemata, and had a subnormal temperature. Four ounces of sterilized olive oil were injected into the gluteal muscles without the production of any local pain or discomfort, and with great benefit to the general condition.

Krueg also kept a lunatic alive for twenty days without loss of weight by the subcutaneous injection of 15 to 30 c.c. of olive oil daily,⁴ and other observers have repeated his experience.⁵

There can be no doubt, then, that feeding by means of the subcutaneous injection of sterilized oil is a feasible enough proceeding, but it must be remembered that its value is strictly limited. Recent experiments by Winternitz⁶ have shown that fat so given is only very slowly absorbed, and that it cannot supply more than 25 Calories to the body per day. In spite, then, of the apparently favourable results reported above the use of fat for subcutaneous feeding must be pronounced almost useless.

The subcutaneous administration of **yolk of egg** has recently been practised by Muggia⁷ in cases of malnutrition in infants and as a substitute for lecithin. The injection is prepared by mixing the yolk of a fresh egg with one-third of its weight of normal saline solution. The mixture is stirred with a glass rod in a previously sterilized vessel, and then strained through gauze. The initial dose is 1 c.c., the injections being made in the buttock or lumbar region. There is no local or general reaction provided aseptic precautions are observed. Gentle massage is performed after the injection. The quantity at each injection may be gradually increased up to 10 c.c., but one should not go above that. He states that the general nutrition and condition of the blood are improved more rapidly under this treatment than under lecithin. G. d'Errico,⁸ however, has

¹ G. Sommer, 'Stoffwechselversuch mit Subcutaner Fettinjection am Menschen,' *Sitzungsber. d. Physik. Med. Gesell. zu Würzburg*, 1897, 26.

² See Jacob, quoted by Gumprecht, *Verhand. d. Cong. f. Inn. Med.*, 1898, 124.

³ *Edin. Med. Journ.*, September, 1893.

⁴ See Lilienfeld, *Zeit. f. Diät. und Physik. Therapie*, ii, 209.

⁵ For example, Fornace and Micheli, *Rif. Med.*, July 14 and 15, 1897 (abstract in *Brit. Med. Journ.*, Epit., September 11, 1897).

⁶ 'Zur Frage der Subcutanen Fetternährung,' *Zeit. f. Klin. Med.*, 1903, l. 80. See also Henderson and Crofutt, *Amer. Journ. of Physiol.*, 1905, xiv 193.

⁷ *Brit. Med. Journ.*, 1899, i, September 30.

⁸ *Giornale internaz. delle Scienze Med.*, August 31, 1902.

found from his experiments that such injections produce only slight and temporary improvement, whilst the use of larger quantities is apt to cause grave lesions of the kidneys.

GAVAGE AND FORCED FEEDING.

Gavage was introduced by Debove in the year 1881.¹ The term was first applied to the method of introducing food into the stomach by means of a tube in cases of obstinate vomiting. Curiously enough, food so introduced is often retained when nourishment swallowed in the usual way is vomited immediately. The meaning of the term has now been extended so as to cover all cases in which food is artificially introduced into the stomach by a tube in excess of the demands of appetite, a proceeding more correctly described as **forced feeding**.

An ordinary soft stomach-tube is employed, and it is only necessary to introduce it into the upper part of the œsophagus; it need not enter the stomach proper. If the pharynx be very sensitive, it may be previously anæsthetized by cocaine.

A mixture consisting of 1 or 2 pints of milk, 3 beaten-up eggs, and 3 ounces of milk-sugar will be found very suitable for administration in this way. Dujardin Beaumetz speaks very highly of powdered meat, of which he gives 100 to 400 grammes daily, stirred up in milk, chocolate, or soup.

A daily ration consisting of 3 pints of milk, to which have been added 3 ounces of milk-sugar (previously dissolved in water by boiling), $\frac{1}{2}$ pint of cream, and a pint of soup strengthened by some protein preparation, such as Nutrose, Plasmon, Tropon, or powdered meat, will be amply sufficient to maintain the nutrition of a patient who is confined to bed, and is very easily administered by the tube.

¹ See Dujardin Beaumetz, *Clinique Thérapeutique*, i. 403.

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